MISCELLANEOUS PAPER EL-82-7

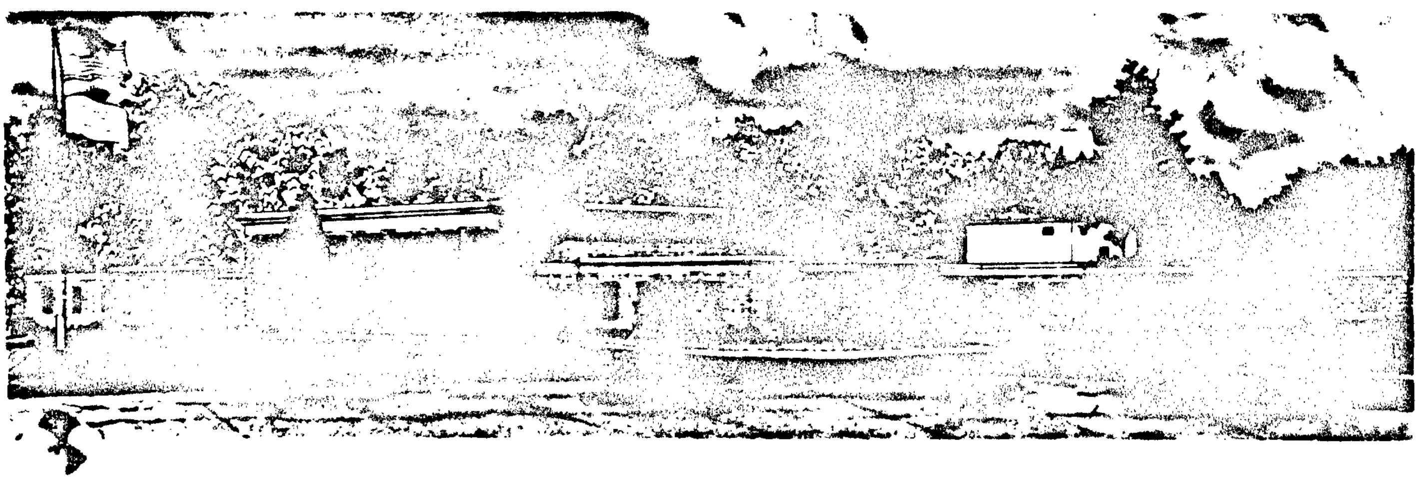
AN ANNOTATED BIBLIOGRAPHY FOR CLEANUP OF HAZARDOUS WASTE DISPOSAL SITES

by

Andrew J. Green

Environmental Laboratory
U. S. Army Engineer Waterways Experiment Station
P. O. Box 631, Vicksburg, Miss. 39180

October 1982
Final Report



Prepared for Office, Chief of Engineers, U. S. Army
Washington, D. C. 20314

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER Miscellaneous Paper EL-82-7	2. GOVT ACCESSION NO. AD-A12[illegible] 833	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) AN ANNOTATED BIBLIOGRAPHY FOR CLEANUP OF HAZARDOUS WASTE DISPOSAL SITES		5. TYPE OF REPORT & PERIOD COVERED Final report 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Andrew J. Green		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS U. S. Army Engineer Waterways Experiment Station Environmental Laboratory P. O. Box 631, Vicksburg, Miss. 39180		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Office, Chief of Engineers, U. S. Army Washington, D. C. 20314		12. REPORT DATE October 1982 13. NUMBER OF PAGES 206
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Available from National Technical Information Service, 5285 Port Royal Road, Springfield, Va 22151.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Bibliographies	Pollution control	Water pollution
CERCLA	Superfund	
Hazardous waste	Toxic waste	

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The indiscriminate and uncontrolled dumping of toxic and hazardous waste has generated environmental and health hazards in almost every state in the United States. In 1980, the Congress of the United States passed legislation (Public Law 96-510, Comprehensive Environmental Response, Compensation, and Liability Act or CERCLA, commonly known as "Superfund") providing funds for cleanup of sites whose existence could not be specifically attributed to known organizations and/or individuals.

(Continued)

20. ABSTRACT (Continued).

The information contained herein is a bibliographical summary of the research and activities conducted in recent years that are related to the design of remedial systems for cleanup of hazardous waste sites.

Health and safety is a key issue during site investigation, construction, and after-action monitoring. The nature and extent of the problem, as well as the technical and economical aspects of remedial site investigations, are discussed. The factors affecting selection of systems and alternatives for control of water and airborne contaminant are also addressed.

Treatment, disposal, and storage systems available are discussed in Parts VI, VII, and VIII. Site monitoring may be required during site investigation, construction, and postclosure. Monitoring procedures are discussed in Part X.

PREFACE

The study reported herein was funded by the Office, Chief of Engineers (OCE), U. S. Army, from Civil Works Appropriation 9623124, General Expense, Civil, 1300-2548-00. The OCE Engineering Division directed, monitored, and reviewed this effort.

The study was conducted during 1981 and 1982 by personnel of the U. S. Army Engineer Waterways Experiment Station (WES), Vicksburg, Miss.: Mr. N. R. Francingues, Mr. D. W. Thompson, Mr. R. J. Larson, Mr. J. H. Dildine, Dr. P. G. Malone, and Mr. A. J. Green, Environmental Engineering Division (EED), Environmental Laboratory (EL); and Mr. W. L. Murphy, Geology and Rock Mechanics Division, Geotechnical Laboratory. This study was supported by Dr. Donald O. Hill, Mississippi State University, Miss.

The work effort was accomplished under the direct supervision of Mr. Francingues, Chief, Water Supply and Waste Treatment Group, EL, and the general supervision of Mr. Green, Chief, EED, and Dr. John Harrison, Chief, EL.

Commander and Director at WES during the study and preparation of this report was COL Tilford C. Creel, CE. Technical Director was Mr. F. R. Brown.

This report should be cited as follows:

Green, A. J. 1982. "An Annotated Bibliography for Cleanup of Hazardous Waste Disposal Sites," Miscellaneous Paper EL-82-7, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

CONTENTS

CONVERSION FACTORS, U. S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

U.S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
acres	4046.873	square metres
feet	0.3048	metres
gallons (U.S. liquid)	3.785412	cubic decimetres
gallons (U.S. liquid) per acre	0.0009	cubic decimetres per square metre
gallons (U.S. liquid) per day	3.785412	cubic decimetres per day
gallons (U.S. liquid) per minute	3.785412	cubic decimetres per minute
inches	25.4	millimetres
pounds (mass)	0.4535924	kilograms
tons (mass) per acre	0.22	kilograms per square metre
tons per year	0.4535924	kilograms per year

AN ANNOTATED BIBLIOGRAPHY FOR CLEANUP OF HAZARDOUS WASTE DISPOSAL SITES

PART I: INTRODUCTION

Purpose

This bibliography contains references to material that should prove useful to Corps of Engineers (CE) personnel and its contractors in providing design and construction support to the U. S. Environmental Protection Agency (EPA). It should also assist implementation of that portion of EPA activities associated with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980 (Public Law (PL) 96-510) (commonly referred to as "Superfund") and related specifically to remedial action for cleanup of uncontrolled hazardous waste disposal sites.

Applicability

The material in this bibliography is provided for the use of those Corps of Engineers Districts and Divisions targeted for Superfund support missions under the provisions of the Corps-EPA Interagency Agreement, dated February 1981, for the execution of PL 96-510. It will also be useful to the EPA and the contractors that may support the Corps and EPA in Superfund remedial actions. Figure 1-1 is a user information matrix intended to help the readers locate those items of greatest interest to them.

A notice was published by EPA in the Federal Register (46FR 2214, 15 April 1981) identifying persons and facilities required to notify EPA of the existence of facilities at which hazardous wastes are or have been stored, treated, or disposed and any known, suspected, or likely releases of hazardous wastes from such facilities (Section 103 (c)).

Section 311(c) (2) of the Clean Water Act (CWA), as amended 33 U.S.C. 1321 (c)(2), sets forth the original requirements for a

CE ORGANIZATIONS AND PERSONNEL

	OCE				LEAD DIVISION						DESIGN DIVISION					LEAD DISTRICT							DESIGN CENTER							
CATEGORIES	PROGRAM MANAGERS	LEGAL	TECHNICAL	SAFETY-INDUSTRIAL HYGIENE	PROJECT MANAGERS	LEGAL	TECHNICAL	CONSTRUCTION	SAFETY	PUBLIC AFFAIRS	PROJECT MANAGERS	LEGAL	TECHNICAL	CONSTRUCTION	SAFETY-INDUSTRIAL HYGIENE	PROJECT MANAGERS	TECHNICAL	PUBLIC AFFAIRS	SAFETY	CONTRACT ADMINISTRATORS	ONSITE PERSONNEL	LEGAL	PROJECT MANAGERS	TECHNICAL	CONSTRUCTION	SAFETY	PUBLIC AFFAIRS	PROCUREMENT	LEGAL
PART I. INTRODUCTION Applicability and Scope	H	M	H	M	H	M	H	H	M	H	H	M	H	H	H	H	M	H	H	L	H	M	H	M	H	H	L	L	M
PART II HEALTH & SAFETY	H	H	H	H	H	M	H	H	H	H	H	M	M	H	H	H	H	H	H	L	H	M	H	M	H	H	L	L	M
PART III REMEDIAL INVESTIGATION Nature & Extent, Technical & Economic Aspects of Problem	H	M	H	M	H	M	H	M	H	M	H	M	M	M	M	H	H	H	H	L	M	M	H	H	H	H	M	L	M
PART IV IDENTIFICATION & SELECTION OF SYSTEMS - Approach, Contaminent Flow Site Parameters	M	L	H	M	H	L	H	M	M	M	H	L	H	M	M	H	H	M	M	L	M	I	H	H	M	H	L	O	L
PART V SITE REMEDIAL TECHNIQUES Surface & Groundwater & Leachate Ctrl, Gas Migration, Windblown Particulates	M	L	M	M	M	M	M	M	H	M	H	M	H	M	H	H	H	M	H	O	H	H	H	H	H	H	O	O	M
PART VI TREATMENT SYSTEMS Physical, Chemical, Biological, Thermal & Photolytic	M	O	M	M	M	L	H	M	M	M	H	M	H	M	M	H	H	L	H	O	H	M	H	H	H	M	O	O	M
PART VII DISPOSAL SYSTEMS Landfills, Deep Wells, Ocean Disposal	M	L	M	M	M	M	H	M	M	M	H	H	H	M	H	H	H	L	H	L	H	H	H	H	H	H	L	O	H
PART VIII TEMPORARY STORAGE Packaging, Shipping, Containment Design & Type, Encapsulation	M	O	M	M	M	L	M	M	M	M	H	L	H	M	M	H	H	L	H	O	H	M	H	H	H	M	O	O	H
PART IX CONSTRUCTION PROCEDURES Techniques & Procedures & Related Health & Safety Issues	M	O	M	M	M	L	H	H	H	M	H	M	H	H	H	H	H	L	H	O	H	M	H	H	H	M	O	M	M
PART X MONITORING Surface & Groundwater, Air Quality, Gases	M	O	M	M	M	L	M	M	H	M	H	M	H	H	H	H	H	L	M	O	H	M	H	H	H	M	O	O	H

LEGEND O = No Interest, L = Slight Interest, M = Moderate Interest, H = High Degree of Interest and Responsibility

Figure 1-1. User Information Matrix.

National Contingency Plan (NCP) to provide for efficient, coordinated, and effective actions to minimize danger caused by discharges to waters of the United States of oil and hazardous substances designated pursuant to Section 311 of the CWA (40 CFR 1510). The most recent revision prior to the enactment of Superfund was published 19 March 1980 (45 FR 17832). Superfund requires the NCP to be revised to reflect and effect the responsibilities and powers created by Superfund (Section 105). The revision of the NCP includes a section of the plan to be known as the national hazardous substance response plan which will establish procedures and standards for responding to releases of hazardous substances, pollutants, and contaminants and will include at a minimum:

a. Methods for discovering and investigating facilities at which hazardous substances have been disposed of or otherwise come to be located.

b. Methods of evaluation, including analyses of relative costs, and remediation of any releases or threats of release from facilities which pose substantial danger to the public health or the environment.

c. Methods and criteria for determining the appropriate extent of removal, remedy, and other measures authorized by CERCLA.

d. Appropriate roles and responsibilities for the Federal, state, and local governments and for interstate and nongovernmental entities in effecting the plan.

e. Provision for identification, procurement, maintenance, and storage of response equipment and supplies.

f. A method for assignment of responsibility for reporting the existence of such facilities which may be located on Federally owned or controlled properties and any releases of hazardous substances from such facilities.

g. Means of ensuring that remedial action measures are cost-effective over the period of potential exposure to the hazardous substances or contaminated materials.

h. Criteria for determining priorities among releases or threatened releases throughout the United States for the purpose of taking remedial action and, to the extent practicable, taking into account the potential urgency of such action for the purpose of taking removal action.

i. A list of national priorities among the known releases or threatened releases throughout the United States based upon the criteria established in accord with Section 105(8)(A).

A postclosure liability fund has been established to provide $200 million to monitor legal dumps and make sure they cause no damage once they are closed.

The Agency for Toxic Substances and Disease Registry was created within the Public Health Service for the purpose of studying health effects and the registration of toxic waste victims.

The President has the responsibility for implementing the legislation. The primary agencies to which the President has delegated responsibility for carrying out the function are listed below:

a. The EPA will manage the fund and implement response and remedial action associated with hazardous sites.

b. The EPA and the Coast Guard will maintain their present distribution of responsibility for hazardous substance spills.

c. The Treasury Department will collect the taxes and enforce the tax structure.

d. The Corps of Engineers will provide management and technical assistance for remedial actions that may be assigned by EPA and accepted by the Corps.

General Considerations

In response to the negative impacts of improper waste disposal, Congress passed the Resource Conservation and Recovery Act (RCRA) in 1976. In accordance with this legislation, EPA developed a "cradle to grave" control system for managing hazardous waste. The system functions to regulate generators and transporters of hazardous waste as well as owners and operators of hazardous waste treatment, storage, and disposal facilities.

The Superfund Act provides $1.6 billion for cleanup of inactive and abandoned hazardous waste disposal facilities. The EPA has overall statutory responsibility for Superfund implementation. Executive Order 12316 further defines the responsibilities of EPA with respect to Superfund.

The EPA program for implementation provides for emergency action and for remedial action at disposal sites. The Corps' responsibility

under the referenced Interagency Agreement is associated only with the remedial action portion of the program (see Figure 1-2).

Remedial action at hazardous disposal sites can consist of, but may not be limited to, the following: field investigations to define the problem and determine its extent; feasibility studies to develop options for remedial action; selection of one or more cost-effective remedial actions; final design and implementation (construction and provision for future monitoring when appropriate).

The Corps' responsibility is limited to providing technical assistance to EPA and to management of design, construction, and installation of monitoring systems for those sites that are selected by EPA and assigned to the Corps.

The Corps will provide technical assistance to EPA during the field investigation and feasibility study phases. This assistance is essential to ensure that the selected remedial action is reasonable with respect to design, construction, and operation. The Corps will also assist EPA in review of state-managed projects for suitability, bidability, and constructability.

The Corps will provide EPA with financial and management information consistent with and easily integrated into EPA's management and financial accounting systems.

The Corps will use its own internal procedures in performing its responsibilities under the Interagency Agreement; however, the Corps will maintain consistency with EPA's overall requirements for the program. Corps Division Engineers and EPA Regional Administrators will operate under the provisions of the Interagency Agreement. There will be no separate regional agreements.

The EPA and the Coast Guard have hazardous response and chemical substances information networks or systems that should be available to Corps Field Operating Agencies and that of their contractors.

The U. S. Army Engineer Waterways Experiment Station (WES) is in the process of becoming affiliated with the EPA's Chemical Substances Information Network (CSIN). This Network is a management system designed to provide access to several chemical data bases. Information

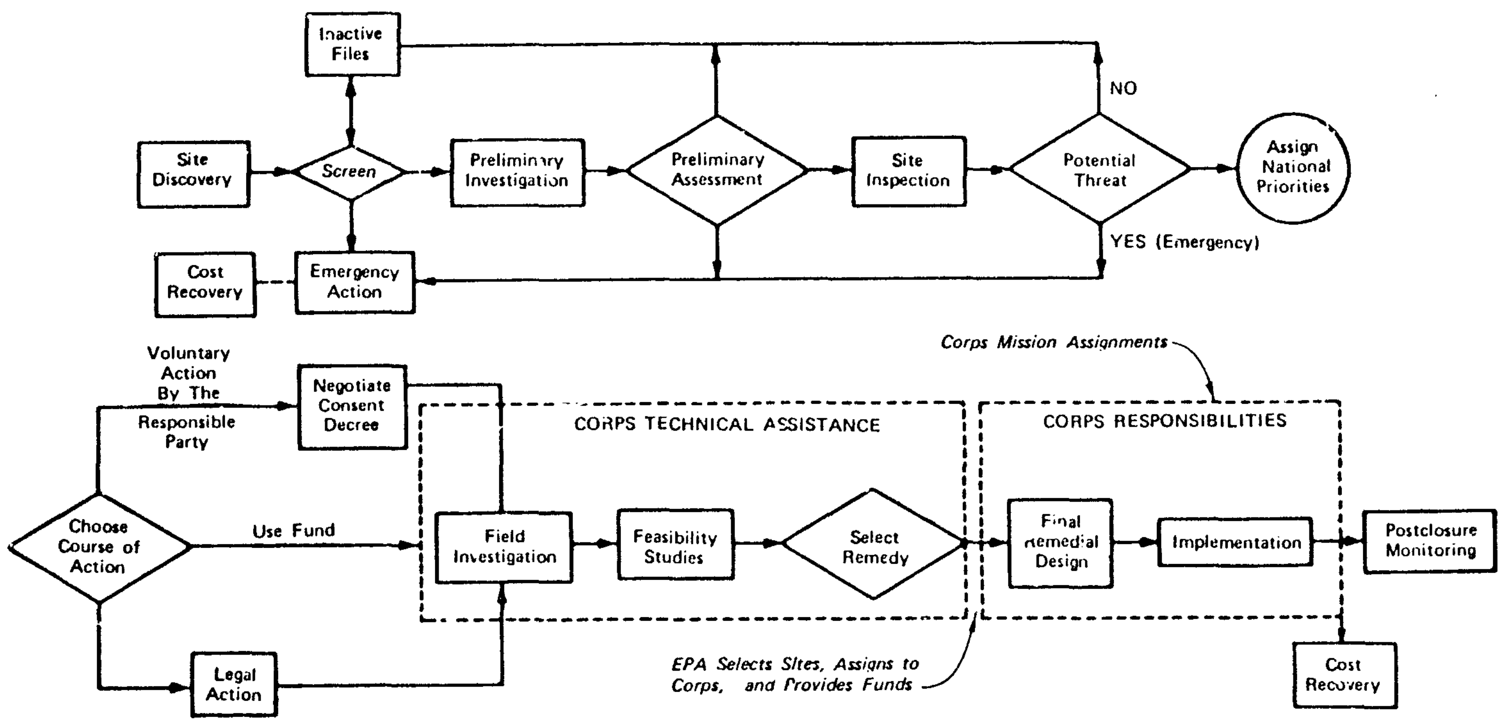


Figure 1-2. Flowchart of EPA's Program for Implementation of Superfund Showing Areas of Corps Technical Assistance and Actual Responsibility.

to be obtained from this computerized information system includes substance identification, physical/chemical properties, exposure, bibliographic data, toxicology, ecological effects, and marketing data. Dr. Sidney Siegal, Administrator, phone 202-426-6260, Chemical Toxic Substances Information Network, Office of Toxic Substances Integration, Office of Pesticides and Toxic Substances, EPA, Washington, DC, is the point of contact for this system.

The Coast Guard has a Chemical Hazard Response Information System (CHRIS) and a Hazard Assessment Computer System (HACS). Dr. Mike Paranouskis, phone 202-426-6260, US Coast Guard, Room 1400, 2100 Second Street, S.W., Washington, DC 20593, is the point of contact for these systems. (A brief discussion of the CHRIS manual has been included in Part III under "Other References," page 3-14.)

Remedial Action Considerations

Responsibility for determining the feasibility of a planned remedial action rests with EPA, but liaison with the Corps during this phase is essential for reasons stated above. Information on the factors for assessing feasibility and the relative weight of each has not been published in final form and therefore may appear in a supplement or revision to this bibliography.

Many of the construction and design techniques associated with the Corps' remedial action portion of the program are not foreign to Corps personnel, but those that are foreign will usually be associated with those sites where the greatest degree of hazard exists. For example, a principal difference in the construction aspect is the high degree of control necessary for proper management of Corps and contractor activities. For health and safety reasons, controls must be strictly adhered to.

Remedial action at a waste disposal site may take the form of control, disposal, treatment, storage, or combinations of these. For example, remedial action may consist of surface flow controls that divert and channel rainfall, thus preventing infiltration of water into the

waste site. Remedial action may also deal specifically with controlling the spread of contaminated groundwater, either by containment or by pumping and treating. Other types of remedial action involve controlling the migration of dangerous gases and vapors from the site, removing the waste material from the site for treatment and disposal, and cleaning up water mains, sewers, wetlands, soils, and water bodies that have been contaminated.

Scope

This bibliography is intended to provide references to related technology and case history references for the designer and construction manager who may develop points of contact and for potential bidders for remedial action activities. This bibliography represents an extensive review of research activities of Department of Defense (DOD) agencies, EPA, and the Coast Guard and of reports of practical experience from agencies and firms involved in cleanup of hazardous waste spills and disposal sites. The user is reminded that the state of the art is rapidly progressing in this area and that this bibliography, voluminous as it is, does not contain all available data.

A Corps of Engineers Engineering Manual entitled "Guidelines for Design and Construction of Remedial Systems for Uncontrolled Hazardous Waste Sites" has been prepared as a companion document and will be updated as soon as possible to reflect new developments in the state of the art and information in technology summaries now being prepared by the EPA.

Supplements to this bibliography will be furnished as appropriate.

PART II: HEALTH AND SAFETY CONSIDERATIONS

Background

Although the overall goal of a remedial action is to protect public health and the environment, field operations at sites containing hazardous substances are obviously dangerous to workers. Planning effective programs for health and safety requires that additional attention be given to ensure that workers are protected from site hazards and that activities performed onsite do not result in any further adverse environmental impact. This aspect of remedial action cannot be overemphasized! To accomplish these goals, two major considerations are required:

a. Detailed planning and evaluation by qualified health personnel before initiating the remedial action.

b. The use of recommended procedures and established techniques during the performance of remedial action.

The specific elements of an acceptable health and safety program should include, as a minimum, facets of occupational medicine, safety, industrial hygiene, training, and first aid.

Even before the initial site visit, planning for health and safety consideration must be made integral with planning of the hazardous waste management program. It should be noted that a basic policy and program of health and safety for hazardous materials response and control are provided for by Federal and state regulations; however, because of the specific nature of each site, it is impossible to develop one health and safety plan that is universally applicable.

Health and Safety Program

Good management and work practices, as well as legal requirements, emphasize the need for placing top priority on health and safety by the Corps and its contractors. Various legal requirements establish the

minimum guidelines for the development and implementation of a comprehensive health and personnel safety program. The Occupational Safety and Health Administration (OSHA) has established regulations designed to decrease accidents associated with the construction site. These regulations are covered in 29 CFR 1926 (Table 2-1). Compliance with applicable OSHA regulations should be a mandatory requirement of the health and safety plan for the remedial action. In addition to the mandatory requirements of OSHA, the Corps, EPA, and the Army Surgeon General have policies and mandatory requirements for occupational health and safety training/certification as well as medical monitoring of agency employees in field activities. The referenced policies and regulations are listed in Table 2-2.

The U. S. Army Medical Bioengineering Research and Development Laboratory has recommended the development of pollutant limit values for people working with toxic and hazardous waste that have been evaluated for several Army problems. Reviews of these reports are included.

The EPA, in addition to providing training on health and safety, has produced technical monographs, reviews of which are included. The abbreviated titles of these monographs are:

a. Medical Emergency Procedures.
b. Communication Problems.
c. Personnel and Equipment Decontamination.
d. Organization of the Operations Area.
e. Health and Personal Safety Program.
f. Overview of Hazards and Investigation Procedures.
g. Training Program Guideline.

Four books published by the American Society for Testing and Materials (ASTM) deal with the extent of hazard of toxic and hazardous chemicals to aquatic life. These books are symposia proceedings covering a wide range of topics including toxicological effects, pollutant concentrations, assessment methods, test equipment, and testing methodology. Four additional books dealing with the identification and toxicology of hazardous chemicals are reviewed herein. Brief descriptions of all eight books are included.

Table 2-1. Citations for Current OSHA Regulations Likely To Be Applicable at Land-Based Disposal Sites

	29 CFR Part 1926
Subpart D	Occupational Health and Environmental Controls (Sections 1926.50 through 1926.57)
Subpart E	Personal Protection (Sections 1926.100 through 1926.107)
Subpart F	Fire Protection (Sections 1926.150 through 1926.155)
Subpart G	Signs and Signals (Sections 1926.200 through 1926.203)
Subpart L	Ladders and Scaffolding (Sections 1926.450 through 1926.452
Subpart O	Mechanical Handling Equipment (Sections 1926.600 through 1926.606)
Subpart P	Excavation and Trenching (Sections 1926.650 through 1926.653)
Subpart S	Tunnels and Shafts (Sections 1926.800 through 1926.804)
Subpart U	Blasting and Explosives (Sections 1926.900 through 1926.914)
	29 CFR Part 1910
Subpart Z	Toxic and Hazardous Substances (Sections 1910.1000 through 1010.1046)
	National Fire Protection Association's "Fire Protection Guide on Hazardous Materials"
	NIOSH/OSHA's "Occupational Health Guidelines for Chemical Hazards"

NOTE: NIOSH = National Institute for Occupational Safety and Health.

Table 2-2. Policies and Regulations Applicable to Remedial Actions

EM 385-1-1, Safety and Health Requirements Manual.
29 CFR 1910, Parts 16, 94, 96, 106, 109, 111, 134, 151, Occupational Health and Safety Standards.
Executive Order 12196, Section 1-201, Sec. (k), Occupational Health and Safety Programs for Federal Employees.
29 CFR 1960.20 (1), Occupational Safety and Health for the Federal Employee.
EPA Occupational Health and Safety Manual, Chapter 7 (1).
EPA Training and Development Manual, Chapter 3, Par. 7 (b).
Occupational Health and Safety Act of 1971, PL 91-596, Sec. 6.
EPA Order on Respiratory Protection (Proposed).
49 CFR, Parts 100-177, Transportation of Hazardous Materials.
EPA Order 1000.18, Transportation of Hazardous Materials.
EPA Order 3100.1, Uniforms, Protective Clothing, and Protective Equipment.

Several articles, an EPA regional offices' field manual for health and safety, and the EPA's "Interim Standard Operating Safety Procedures" were also reviewed. Descriptions are included.

Report: Rosenblatt, D. H., Dacre, J. C., and Cogley, D. R. 1980. "An Environmental Fate Model Leading to Preliminary Pollutant Limit Values for Human Health Effects," Technical Report No. 8005, USATHAMA, DRCPM-DR-T, Aberdeen Proving Ground, Md.

Subject: Health and Safety.

Description: A report that describes a step-by-step methodology so that preliminary pollutant limit values (PPLV's) can be calculated for environmental chemicals in a consistent and easily understood manner from toxicity data or from values promulgated by various agencies. Such PPLV's would not be considered health standards but would be used for preliminary design criteria of pollution control systems. The values would apply until the required toxicological data base could be sufficiently developed to allow the limit values to be reassessed. Only human health effects are addressed in the present treatment. An acceptable daily dose, D_T, is calculated from the best available standards or toxicity data. Calculations are made for each probable exposure route to estimate the concentrations at the pollutant source(s) that would lead to D_T in a human being. A final source concentration value (PPLV) is calculated by normalizing the source concentration value for all probable exposure routes.

Technical Monograph: USEPA. 1981. "Technical Methods for Investigating Sites Containing Hazardous Substances - Medical Emergency Procedures," Technical Monograph No. 14, 5 pp.

Subject: Medical Emergency Procedures.

Description: To respond properly to a medical emergency, field staff must apply first aid and then immediately transport the victim to a hospital. This monograph describes training requirements and contingency planning methods that provide emergency preparedness for hazardous substance site investigations.

Technical Monograph: USEPA. 1981. "Technical Methods for Investigating Sites Containing Hazardous Substances - Communications Procedures," Technical Monograph No. 13, 8 pp.

Subject: Communications Procedures.

Description: A reliable field communication system is required to ensure rapid response to emergency situations and to enhance the effectiveness of the field investigation team. The communications center is located in the command post and consists of an external network, used primarily for obtaining offsite emergency aid, and an internal network, used for both emergency and work-related communications. At least two means of communication should be available in each of the networks. Communication methods are limited solely by resources available and the imagination of the team members.

The complexity of the communications system will vary according to the task, the hazard present, the terrain, and the resources available. For most surveys and inspections, a team can use public telephones for communications with the management center to report results or problems or to adjust the work schedule. However, the communications procedures are complicated by the difficulties in hearing and speaking that are created by protective equipment, the distances involved in traveling across an organized work site, and large field parties.

Technical Monograph: USEPA. 1981. "Technical Methods for Investigating Sites Containing Hazardous Substances - Personnel and Equipment Decontamination," Technical Monograph No. 23, 18 pp.

Subject: Personnel and Equipment Decontamination.

Description: Hazardous substances are acutely or chronically toxic or otherwise hazardous to man, animals, or plants. Decontamination is the process for neutralizing or removing contaminants. To avoid contamination of field inspectors and the subsequent transfer of hazardous substances to clean areas, a thorough decontamination process is required for personnel and equipment involved in field inspections or investigations. This monograph presents specific decontamination procedures and equipment needs for each level of protective clothing described in Monograph 9 of this series. It also describes decontamination of field equipment and the importance of contamination avoidance.

The decontamination process is designed to control the spread of contaminants to clean areas by physically removing or chemically neutralizing the contaminants on protective clothing and equipment used at hazardous substance sites. This monograph covers decontamination procedures designed to support inspections and field investigations. Although these procedures are technically sufficient to support long-term cleanup operations, a permanent or semipermanent decontamination facility would be more appropriate.

Contamination avoidance is the first and best method for preventing the spread of contamination from a hazardous site. Every effort should be made to prevent direct contact with the

contaminant. Careful planning, knowledge of the contaminant, and attention to where one puts his hands and feet are all important. Simple common-sense rules of contamination avoidance include not sitting down, not leaning against drums or debris, and not putting equipment on the ground.

Technical Monograph: USEPA. 1981. "Technical Methods for Investigating Sites Containing Hazardous Substances - Organization of the Operations Area," Technical Monograph No. 8, 15 pp.

Subject: Organization of the Operations Area.

Description: The safe, efficient conduct of a field investigation at a hazardous substance site can best be accomplished by controlling access to and from the site, by delineating those areas considered as potentially hazardous, and by associating certain areas of the site with certain work activities. The monograph discusses various ways of organizing the site to accomplish the work objectives while maintaining the needed degree of onsite and offsite safety and security.

The investigation of a hazardous substance site involves potential exposure of the investigation team and the surrounding community to varying degrees of hazards. One way to decrease the possibility of exposure is by organization of the site into an operations area that limits access, provides security for the site, and provides a buffer zone around the site. The actual size and shape of the operations area will vary depending on the hazard associated with the site, the type of work undertaken, wind direction and speed, terrain, presence and distribution of the surrounding community, and political or public relations considerations.

Technical Monograph: USEPA. 1981. "Technical Methods for Investigating Sites Containing Hazardous Substances - Health and Personal Safety Program," Technical Monograph No. 3, 13 pp.

Subject: Health and Personal Safety Program.

Description: Fitness criteria and scheduled periodic evaluations are required to ensure that only medically sound individuals participate in field operations involving hazardous substances and that these individuals' health status is maintained. Additional medical support is required to handle emergency and postexposure situations. This monograph describes the basic elements of such a health and personal safety program.

The purpose of a health and safety program is to ensure the protection of individuals engaged in hazardous work. Such a program should consist of:

(1) A comprehensive health surveillance program.

(2) A safety program composed of specific guidelines and standard operating procedures.

(3) A hands-on training program with periodic refresher training.

(4) Assignment of safety officers within the organization to ensure compliance with the program.

It is the purpose of this monograph to explain the health surveillance program. Such a program must strike a balance between providing a safe and healthful work setting and respecting the individual's right to privacy.

Technical Monograph: USEPA. 1981. "Technical Methods for Investigating Sites Containing Hazardous Substances - Overview of Site Hazards and Investigation Procedures," Technical Monograph No. 12, 22 pp.

Subject: Overview of Hazards and Investigation Procedures.

Description: Field operations at sites containing hazardous substances are obviously dangerous to workers. This document provides a description of these hazards and of general safety procedures to assemble elements logically found in other monographs in this series.

Workers investigating hazardous substance sites are exposed to a number of hazards, some of which are obvious while others are unapparent and therefore easily overlooked. Personal protection requires a multidisciplinary approach to safety. Each aspect of the safety program must be understood by a safety officer who is assigned the overall responsibility for safety for the investigation team. The safety officer must then integrate the components into a unified program to fully protect field personnel. These components include:

(1) An understanding of the potential hazards.

(2) The overall health and safety plan dealing with medical monitoring and medical response.

(3) Comprehensive training programs.

(4) The preparation of site safety plans designed to protect the field investigation team from hazards peculiar to a specific site.

Technical Monograph: USEPA. 1981. "Technical Methods for Investigating Sites Containing Hazardous Substances - Training Program," Technical Monograph No. 2, 15 pp.

Subject: Training Program Guidelines.

Description: The investigation of sites containing hazardous substances carries with it a degree of risk from possible exposure to toxic substances and from the possibility of dangerous chemical interaction of the substances. To minimize the risk to individuals and the public, anyone involved in such investigations must be trained in the use of proper protective equipment and techniques of investigation. Untrained personnel should never be allowed to participate onsite.

This monograph contains guidelines for the specialized training necessary for members of a field investigation team. This training focuses on proper investigation procedures, use of protective clothing and equipment, and emergency and safety procedures. It is assumed that team members are qualified in the technical disciplines needed for evaluation of sites.

A description of a basic training course is followed by discussions of necessary specialized training such as first aid and cardiopulmonary resuscitation (CPR). In addition, requirements for periodic refresher training are discussed, as well as considerations of training records and certifications. Finally, a list of sources of relevant training is included.

Book: ASTM. 1978. STP-657-Estimating the Hazard of Chemical Substances to Aquatic Life, American Society for Testing and Materials, Philadelphia, Pa., 283 pp.

Subject: Extent of Hazard - Aquatic Life

Description: This publication may be of value to anyone (whether from industry, government, or academia) involved in the assessment of hazards that chemicals pose to aquatic life. Topics covered include toxicological effects, environmental concentration, environmental fate, hazard assessment, and evaluation of proposed test procedures for estimating hazards to aquatic life.

Book: ASTM. 1980. STP-707-Aquatic Toxicology (Third Symposium), American Society for Testing and Materials, Philadelphia, Pa., 417 pp.

Subject: Extent of Hazard - Aquatic Life.

Description: From the proceedings of the Third Annual Symposium on Aquatic Toxicology, this volume represents essentially all the basic and applied aspects of aquatic toxicology. It addresses such subjects as biological monitoring, toxicology methods development, bioconcentration, water quality management, effluent testing, physiology and behavior, and single toxicant effects.

Book: ASTM. 1977. STP-634-Aquatic Toxicology and Hazard Evaluation, American Society for Testing and Materials, Philadelphia, Pa., 315 pp.

Subject: Extent of Hazard - Aquatic Life.

Description: This volume attempts to assess the safety of chemicals that directly or indirectly affect water-based ecosystems. Twenty-two papers provide state of the art for research approaches, new applications of old methods, and new data on several pesticides and other chemicals.

Book: ASTM. 1979. STP-667-Aquatic Toxicology (Second Symposium), American Society for Testing and Materials, Philadelphia, Pa., 403 pp.

Subject: Extent of Hazard - Aquatic Life.

Description: This book presents 25 papers that assess the effects of pesticides, contaminants, and other chemical factors in aquatic environments. This publication is a continuation of the first (STP 634), in that progress is shown in certain areas of methodology and equipment, and certain rationales and philosophies are updated.

Book: Bretherick, L. 1979. Handbook of Reactive Chemical Hazards, 2nd ed., Ann Arbor Science, Wobrun, Mass., 1310 pp.

Subject: Operations and Safety Considerations.

Description: This edition of an established reference on chemical safety has been updated and expanded with over 2,000 new entries, including 150 new group hazard items. The addition of a name index to all the compounds listed makes the Handbook a quick reference guide. With over 7,000 entries, this is a good collection of information on reactive chemical hazards. The author tells specifically where to find:

(1) Stability data on single specific compounds.

(2) Data on possible violent interaction between two or more components.

(3) General data on a class of compounds.

(4) Information on identity of individuals in a known hazardous group.

(5) Structures associated with explosive instability.

(6) Fire-related data.

Book: Walters, D. B. 1980. Safe Handling of Chemical Carcinogens, Mutagens and Teratogens, and Highly Toxic Substances, 2 Vol., Ann Arbor Science, Woburn, Mass., 661 pp.

Subject: Operations and Safety Considerations.

Description: This two-volume set contains material presented at the American Chemical Society meeting in April 1979. It offers effective guidelines for the control and use of hazardous agents in research, industrial, and academic laboratories. Topics covered include the appropriate laboratory design, handling, and management procedures for hazardous compounds; chemical monitoring and medical surveillance; chemical classification; structure activity and toxicity prediction; and spill control, degradation, and deactivation.

Book: Gleason, M. N., et al. 1969. Clinical Toxicology of Commerical Products; Acute Poisoning, 3d ed., The Williams & Wilkins Co., Baltimore, Md.

Subject: Operations and Safety Considerations.

Description: This book contains alphabetical compilation of 3,000 major chemical substances (ingredients) found in widely used commercial products, and gives toxicity information and a toxicity rating for each ingredient. In addition, the manual contains a trade name index for 17,000 products, identifies the manufacturers, lists the ingredients for each product, and identifies the toxic components.

Book: Christen, H. E., Luginbyhl, T. T., and Carroll, B. S. 1975. Registry of Toxic Effects of Chemical Substances, 1975 ed., U. S. Government Printing Office, Washington, D. C., 1296 pp.

Subject: Operations and Safety Considerations.

Description: This volume identifies toxicity (to man, animals, and aquatic life) of most known organic and inorganic chemicals and identifies carcinogenic, teratogenic, and mutagenic nature, if any.

Article: Melvold, R. W., Gibson, S. C., and Royer, M. D. 1981. "Safety Procedures for Hazardous Materials Cleanup, Management of Uncontrolled Hazardous Waste Sites," U. S. Environmental Protection Agency and American Society of Civil Engineers, pp. 269-276.

Subject: Operations and Safety Considerations.

Description: EPA and contractor personnel at hazardous substance cleanup operations face the risk of direct chemical exposure or exposure to chemical-caused hazards such as fire, explosion, or oxygen depletion. Many of the perils of entry, assessment, and cleanup of hazardous waste sites have been recognized and addressed by numerous authors, but a number of important safety topics have yet to be adequately covered.

This paper describes a project that: (1) identifies specific hazardous substance cleanup tasks that require improved safety guidance and (2) provides monographs containing the best available safety guidance for selected topics. Two of the safety monographs produced as a result of the project are summarized. The monographs are: (1) air quality monitors and (2) medical surveillance for hazardous materials cleanup personnel.

Article: Gallagher, G. A. 1981. "Health and Safety Program for Hazardous Waste Site Investigations," Ecology and Environment, Inc., Buffalo, N. Y., paper presented at Assoc. of Engr. Geologists, 7 Feb 81, Boston College, Boston, Mass.

Subject: Safety Considerations.

Description: This paper discusses health surveillance monitoring programs and respiratory protection, levels of safety equipment, makeup of site entry teams, decontamination, and training to prepare field personnel to operate safely under a variety of field conditions.

Manual: USEPA. 1981. "Field Health and Safety," Region 4, Altanta, Ga., 65 pp.

Subject: Health and Safety Considerations.

Description: The purpose of this manual is to outline a safety program for employees who are or could be, by virtue of their duties and responsibilities, engaged in field activities. It discusses safety programs from prearrival through postsite departure.

Procedures: USEPA. 1981. "Interim Standard Operating Safety Procedures," Washington, D.C.

Subject: Operations and Safety Considerations.

Description: The purpose of this document is to provide recommendations for selected safety procedures. Although every endeavor onsite or offsite involves some degree of consideration for worker protection and safety, the purpose of this document is to provide criteria for standard operating procedures primarily related to site control and entry. The following phases are addressed in this document:

(1) Site entry - general measures.

(2) Site entry - initial survey and reconnaissance.

(3) Site entry - personnel protection.

(4) Site control - site work areas.

(5) Site control - decontamination.

Other References

JRB Associates. "Handbook for Remedial Action at Waste Disposal Sites," Appendix D, EPA-625/6-82-006, USEPA, Cincinnati, Ohio.

Rosenblatt, D. H., and Small, M. J. "Preliminary Pollutant Limit Values for Alabama Army Ammunition Plant," Technical Report 8105, U.S.A.M.B.R.O.L., Frederick, Md.

Rosenblatt, D. H. 1981 (Apr.) "Pollutant Limit Value Estimates for Five Pollutants at the Bangor Naval Submarine Base," Draft, U.S.A.M.B.R.O.L., Frederick, Md.

Ghassemi, M., Quinlivan, S., and Casey, H. 1976. "Disposing of Small Batches of Hazardous Wastes," SW-562 USEPA, Washington, D. C., 21 pp.

Schweitzer, G. E. 1981. "Risk Assessment Near Uncontrolled Hazardous Waste Sites: Role of Monitoring Data, Management of Uncontrolled Hazardous Waste Sites," U. S. Environmental Protection Agency and American Society of Civil Engineers, pp. 238-247.

Muthamel, M. S. "Hazardous Substance Site Ambient Air Characterization to Evaluate Entry Team Safety, Management of Uncontrolled Hazardous Waste Sites," U. S. Environmental Protection Agency and American Society of Civil Engineers, pp. 280-284.

Borchardt, J. A. 1981. "Sludge and Its Ultimate Disposal," Ann Arbor Science, Woburn, Mass., 286 pp.

Pojasek, R. B. 1980. "Toxic and Hazardous Waste Disposal: Vol 4. New and Promising Ultimate Disposal Options," Ann Arbor Science, Woburn, Mass., 314 pp.

NIOSHA/OSHA Occupation and Health Guidelines.

National Fire Protection Association. 1972. Fire Protection Guide on Hazardous Materials, 4th edition, Nos. 325A, 325M, 49, 491M, and 704M, Boston, Mass.

National Fire Protection Association. 1969. Fire Protection Handbook, G. H. Tryon (ed.), 13th edition, Boston, Mass.

Erven, L. W. 1970. First Aid and Emergency Rescue, Glencoe Publishing Co., New York, N. Y.

American National Red Cross. 1972. First Aid Textbook, Washington, D. C.

Factory Mutual Engineering Corp. 1967. Handbook of Industrial Loss Prevention, 2nd edition, McGraw-Hill, New York.

Zajic, L., and Himmelman, W. A. 1978. Highly Hazardous Materials Spills and Emergency Planning, Marcel Dekker, Inc., New York, N. Y.

Patty, F. A. 1963. Industrial Hygiene and Toxicology, 2nd edition, Vol. II, Interscience, New York.

PART III: REMEDIAL INVESTIGATION

Introduction

Remedial action at any uncontrolled hazardous waste disposal site is preceded by an extensive site investigation. In most cases, the site investigation is conducted in sequenced phases. The initial site description is usually completed by the state or Federal agency that is screening the site to identify the hazards associated with it and to determine its ranking as a prospective candidate for cleanup activities. In this screening operation, information often is collected that is not directly applicable to engineering problems, and critical factors may be omitted that are necessary for selection of specific remedial measures. At various stages in the design of remedial measures, it becomes necessary to develop specific information for evaluation of particular processes; i.e., additional phases of data collection become necessary as the remedial program evolves (Figure 3-1). Any remedial investigation report generated by a site inspection team will include a description of the physical layout of the site and the activity at the site, i.e., treatment, storage, concentration, reclaiming of waste, etc. The available literature in this area is limited and does not easily lend itself to an organized grouping of references by activities; however, three groupings have been made: Determination of Nature and Extent of Problems, Technical Aspects, and Economic Aspects. To supplement these, a listing of sources of data for site assessment (Table 3-1) is included.

Determination of Nature and Extent of Problems

This determination is essential to the assignment of priorities of sites scheduled for cleanup. It may include waste inventories, personal interviews, records searches, monitoring, analytical testing, and reviews of meteorological, hydrological, and geological data. Table 3-2 suggests that this investigation can become lengthy and involved.

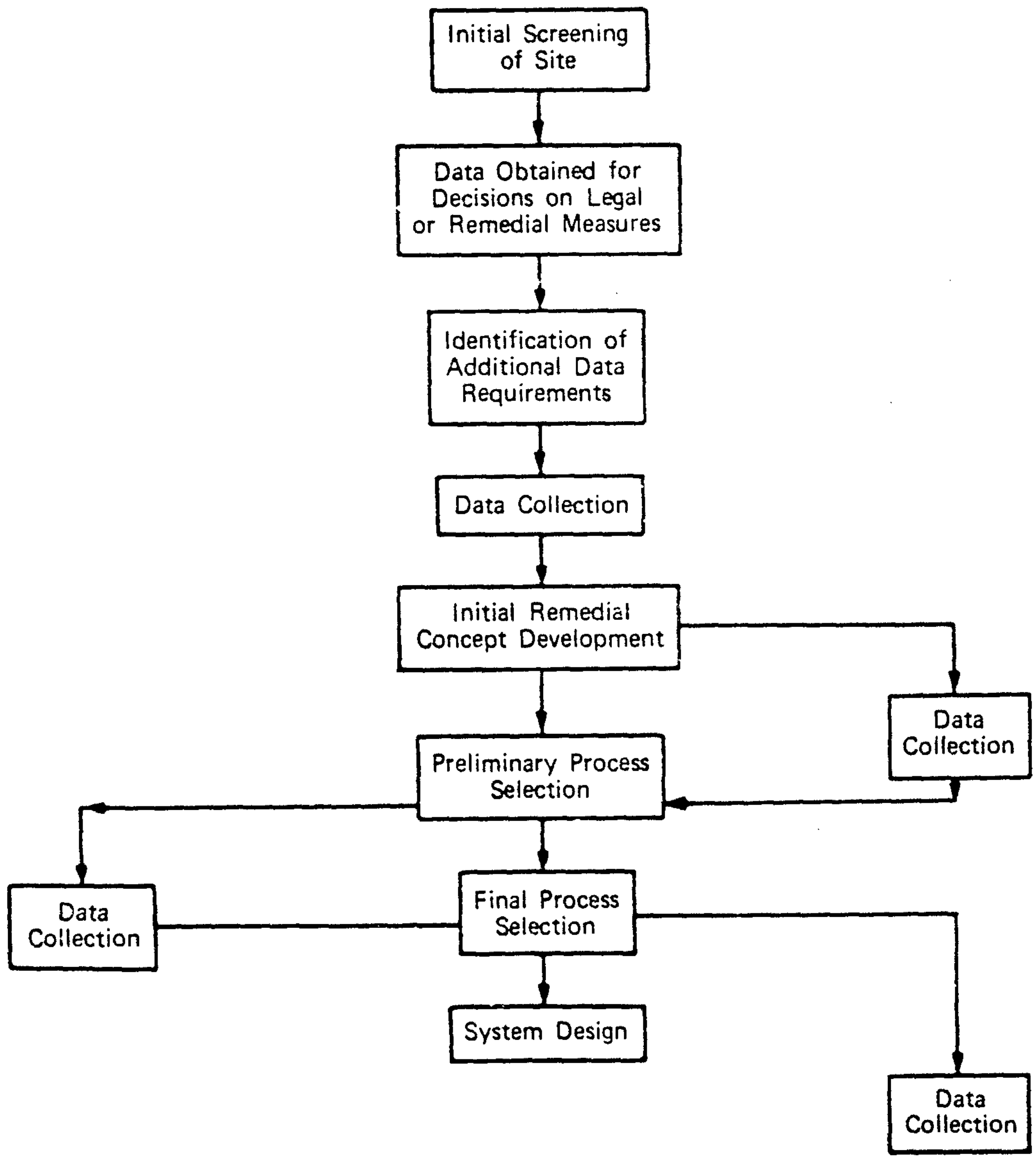


Figure 3-1. Sequence of Investigative Activities.

Table 3-1. Sources of Data for Site Assessment

Substance Characterization	Pollutant Dispersal Pathways	Receptor Characterizations	Site Management Practices
1. Site Records A. Inventories B. Shipment manifests C. Permits 2. Waste Generator Records 3. Personal Interviews A. Site personnel B. Public officials C. Private citizens 4. Monitoring/Sampling Data (If Available)	1. Geology A. USGS* publications B. USGS topographic maps C. State geological surveys 2. Hydrology A. USGS water resource division B. State water resource divisions C. Flood insurance rate maps from HUD** 4. Aerial Imagery A. EPA sources B. Other sources (1) NASA† (2) Local planning agencies (3) Private companies (4) National Weather Service (5) EPA site reports	1. U. S. Public Health Service 2. Local Planning Agencies 3. Federal/State Fish and Wildlife Departments 4. Area Universities 5. Local Naturalists 6. Aerial Imagery 7. Medical Reports 8. News Sources	1. State and Local Regulatory Offices 2. Review Site Management 3. Personal Interviews 4. Aerial Photo 5. OSHA/NIOSHA 6. Fire Departments

* U. S. Geological Survey
** Housing and Urban Development
† National Aeronautics and Space Administration

Table 3-2. Checklist of Major Features Included in Site Description

Site Sketch

The following features should be included:

Site boundaries	Loading/unloading areas
Entrance and exit locations	Office areas
Access roads	Water well locations
Disposal locations	Treatment facility locations
Storage areas	Surface drainage

Chemical Storage Facilities Description

Storage tanks: number, volume, condition, content, etc.
Drums: number, volume, contents, condition, labeling, etc.
Lagoons and surface pits: number, size, use of liner, content, etc.

Treatment Systems

The presence of any treatment system should be noted. These can be difficult to evaluate visually. General appearance, maintenance, and integrity should be visually assessed; operators should be asked for any monitoring records; presence of odors should be noted; any effluents or residues should be visually characterized; and types of wastes and volumes treated should be described.

Incinerators	Volume reduction
Flocculation/filtration	Waste recycling
Chemical/physical treatment	Other
Biological treatment	

Disposal Facilities

The presence and use of any of the following operations should be noted. A description of the size, use of liners, soil type, presence of leachate, and dead vegetation or animals should be obtained. A description of management practices should be obtained. Site workers should be interviewed. [illegible]ce types should be described.

Landfills	Surface impoundments
Land forms	Underground injection
Open dump	Incineration

(Continued)

Table 3-2 (Concluded)

Hazardous Substance Characteristics

Manifests, inventories, or monitoring reports should be obtained. Markings on containers should be noted.

Chemical identities	Container markings
Quantities	Monitoring data, other analytical data
Hazard characteristics (toxic, explosive, flammable, etc.)	Physical state (liquid, solid, gas, sludge)

Geohydrological Assessment

Situations that promote hazardous substance migration, i.e., porous soils, porous or fractured bedrock formations, shallow water tables, flowing streams or rivers nearby, etc., should be included in the site report.

Geology	Water wells (use and water depth)
Soil or rock type	Erosion potential
Surface water features	Flooding potential
Surface drainage pattern	
Groundwater conditions/depths/movement	

Identification of Sensitive Receptors

Number and location of private homes	Other public use areas (roads, parks, etc.)
Public buildings	Natural areas

Three of the EPA entries are monographs:

a. Introduction to Site Investigation.

b. Preliminary Assessments.

c. Work Plan Development.

One article appearing in an American Society of Civil Engineers (ASCE) publication addresses this issue of priorities. Reviews of these documents are included. From these documents, the fact that there are significant economic as well as technical aspects of the subject is obvious.

Technical Monograph: USEPA. 1981. "Technical Methods for Investigating Sites Containing Hazardous Substances - Introduction to Site Investigations," Technical Monograph No. 1, 12 pp.

Subject: Determination of Nature and Extent of Problem.

Description: This monograph presents an overview of the characterization of the environmental and public hazard of sites contaminated with hazardous substances. A brief description of the nature of a field investigation and definitions of key terms are presented.

Technical Monograph: USEPA. 1981. "Technical Methods for Investigating Sites Containing Hazardous Substances - Preliminary Assessments," Technical Monograph No. 4, 8 pp.

Subject: Technical Hydrological Aspects.

Description: Following site discovery and the initial consideration for the need of emergency action, a more thorough evaluation of site history and conditions is required for regulatory agency decisions. This review should normally consist of two elements: preliminary assessment and a field inspection (if required). The former occurs entirely offsite, while the latter requires site entry.

The purpose of this monograph is to detail the work required to accomplish a preliminary assessment. With the information gathered from preliminary assessment, emergency action needs can be addressed, the need for further investigation or remedial work can be assessed and sites ranked accordingly, or a site may be dismissed as requiring no further action. The knowledge resulting from preliminary assessment allows more accurate safety planning if field work is required and provides a cost-effective method that minimizes the unnecessary commitment of expensive resources. This last benefit alone supports the logic of doing preliminary assessment prior to site inspection or field investigation.

Technical Monograph: USEPA. 1981. "Technical Methods for Investigating Sites Containing Hazardous Substances - Work Plan Development," Technical Monograph No. 6, 19 pp.

Subject: Disposal Determination of Nature and Extent of Problem.

Description: A work plan describes the purpose and goals of a field investigation and details the methodologies and safety procedures to be used. This monograph describes the organization of a work plan and provides an example of a work plan for a hazardous substance site investigation.

This monograph also details the work plan organization. While the work plan is a formal document that should be brief and concise, the exact organization presented can be adjusted to suit the preference of individual investigation teams. However, it should always have the following basic elements:

(1) A summary of background information on the site with emphasis on how this information can be used to identify investigation objectives and to develop a work plan.

(2) A statement of objectives and goals of the investigation. Typical investigation goals include hazardous substance inventory and documentation of pollutant migration.

(3) Investigation methods required to characterize the site. Often these include a sampling plan which describes sample types, sampling locations, sampling procedures, and field quality control. Other frequently used methods describe monitoring well installation, geohydrological boring, waste inventory, etc.

Article: Nelson, A. B., and Young, R. A. 1981. "Location and Prioritizing of Abandoned Dump Sites for Future Investigations, Management of Uncontrolled Hazardous Waste Sites," U. S. Environmental Protection Agency and American Society of Civil Engineers, pp. 52-62.

Subject: Setting priorities for Remedial Action Investigation.

Description: The methodology described in this paper to locate and classify abandoned dump sites was developed in Monroe County, New York, in response to a 1978 county legislature request to locate potential "Love Canal" type problems and a 1979 New York State law requiring counties to identify abandoned sites. The system is designed to evaluate and set priorities on a large number of sites for more detailed investigation. While not all points will be applicable in every part of the country, the general approach will allow government agencies to focus limited resources on those sites that pose the greatest potential impact on human health.

This paper is a brief description of a methodology that will be fully described in a final report to EPA to be completed in 1982.

Technical Aspects

One of the predominant technical problems is associated with quantification of the groundwater regime. There is a wealth of literature on groundwater modeling and monitoring. There are other pollution pathways to be considered involving terrestial and aquatic flora and fauna and airborne pollutants. The EPA's technical monographs applicable to these items are:

a. Water Sampling Methods for Field Investigations.

b. Hydrogeological Techniques.

c. Sampling for Biological Specimens.

Articles and reports reviewed for this bibliography cover the following topics:

a. Geophysical Surveys--Radar and Resistivity.

b. Groundwater Modeling Techniques.

c. Groundwater Monitoring Techniques.

d. Air Quality Monitoring and Modeling.

Additional references on technical aspects are listed at the end of Part III.

Technical Monograph: USEPA. 1981. "Technical Methods for Investigating Sites Containing Hazardous Substances - Water Sampling Methods for Field Investigations," Technical Monograph No. 16, 21 pp.

Subject: Water Sampling.

Description: Water, both surface and subsurface, is an important vehicle for the movement of contaminants through the environment. This monograph outlines the equipment, methods, and containers necessary to successfully sample both surface water and groundwater.

For a large number of field investigations of hazardous substance sites, the sampling and analysis of surface and groundwater is a major focal point. In some cases, the analysis of a sample taken offsite may be the initial indicator that the site is a pollution source. Once the substances associated with the

site have been characterized in preliminary assessment, or from analysis of samples taken onsite, surface water and groundwater samples may be necessary to help establish the existence and extent of contaminant migration. Such data help investigators identify populations at risk and determine appropriate remedial actions.

Surface water and groundwater samples are usually considered environmental samples. There are instances, however, when surface water and groundwater samples may be more highly concentrated, even to the degree that they may be considered hazardous samples. The site entry team leader or project manager must decide how such samples should be handled. Visual indicators of high concentrations include coloration, turbidity, odor, multiphasic layering, and spontaneous formation of precipitates.

<u>Technical Monograph</u>: USEPA. 1981. "Technical Methods for Investigating Sites Containing Hazardous Substances - Hydrogeological Techniques," Technical Monograph No. 21, 19 pp.

<u>Subject</u>: Hydrogeological Techniques.

<u>Description</u>: Hydrogeological techniques are useful in assessing the mobility of hazardous substances, the extent of contamination, and the existence of buried contaminated materials and containers. The purpose of this monograph is to acquaint investigators with the hydrogeological techniques (including drilling and geophysical methods) that are useful in a field investigation. This monograph is not intended to prepare nonhydrogeologists to successfully complete a hydrogeological study.

Hydrogeological techniques are employed during the investigation of hazardous substance sites in order to answer the following set of questions concerning possible impacts on groundwater:

(1) Have any contaminants entered the ground?

(2) If so, have they reached the water table?

(3) If they have, then where have they gone, where are they going, and how fast are they moving?

Unfortunately, it is not always possible to answer all three questions. This monograph will attempt to give the reader some understanding of the kinds of techniques available, the problems inherent in using them, and what can be accomplished. This information can be used to develop answers to the above questions.

<u>Technical Monograph</u>: USEPA. 1981. "Technical Methods for Investigating Sites Containing Hazardous Substances - Sampling for Biological Specimens," Technical Monograph No. 18, 10 pp.

<u>Subject</u>: Biological Sampling.

Description: One of the objectives of a hazardous substance site investigation is to document the migration of toxic substances into the environment. Sample collection, followed by chemical analysis, of living organisms is a sensitive means of detecting the presence of contaminants in the environment surrounding a hazardous substance site. This monograph addresses some of the types of habitats of organisms indicative of pollution and presents examples of the standard sampling equipment, methodology, and preservation techniques used to accomplish this investigative task.

The investigation of a hazardous substance site through a biological sampling program offers a method additional to that of standard analytical procedures, for documenting the migration of contaminants into the environment. In addition to the direct effects on organisms when a nonliving or abiotic factor, such as a chemical contaminant, is introduced into the environment, there is also, typically, an ecological response.

Article: Horton, K. A., Morey, R. M., Isaacson, L., and Beers, R. H. 1981. "The Complementary Nature of Geophysical Techniques for Mapping Chemical Waste Disposal Sites: Impulse Radar and Resistivity, Management of Uncontrolled Hazardous Waste Sites," U. S. Environmental Protection Agency and American Society of Civil Engineers, pp. 158-164.

Subject: Geophysical Survey--Radar and Resistivity.

Description: Geophysical mapping at waste disposal sites has provided a direct comparison of results obtained from the application of two different geophysical techniques: (1) electrical resistivity (ER) and (2) electromagnetic impulse or ground penetrating radar (GPR). A correlation between data acquired by these two methods is reported in this paper. The two types of data can be used in a complementary manner since the radar signatures give geological meaning to the resistivity and the resistivity can be used to estimate radar system capabilities and predict the depth of penetration of the radar signals in the site geology.

Report: Nelson, R. W. 1978. "Evaluating the Environmental Consequences of Groundwater Contamination," BCS Richland, Inc., Richland, WA, Report to the U. S. Energy Research and Development Administration.

Subject: Groundwater - Modeling Techniques.

Description: The environmental consequences of subsurface contamination problems can be completely and effectively evaluated by fulfilling the following five requirements:

(1) Determine each present or future outflow boundary of contaminated groundwater.

(2) Provide the location/arrival-time distributions.

(3) Provide the location/outflow-quantity distributions.

(4) Provide these distributions for each individual chemical or biological constituent of environmental importance.

(5) Use the arrival distributions to determine the quantity and concentration of each contaminant that will interface with the environment as time passes.

The arrival distributions on which these requirements are based provide a reference point for communication among scientists and public decisionmakers by enabling complicated scientific analyses to be presented as simple summary relationships.

A steady, two-dimensional flow system is used to demonstrate the application of location/arrival-time and location/outflow-quantity curves in determining the environmental consequences of groundwater contamination. The subsurface geologic and hydrologic evaluations needed to obtain the arrival results involve a sequence of four phases: system identification, new potential determination, flow systems kinematics, and contaminant transport analysis. Once these phases are completed, they are effectively summarized and easily used to evaluate environmental consequences through the arrival distributions.

Report: Fenn, D., et al. 1977. "Procedures Manual For Groundwater Monitoring at Solid Waste Disposal Facilities," EPA/530/SW-611, U. S. Environmental Protection Agency, Washington, D. C. 269 pp.

Subject: Groundwater - Monitoring.

Description: This manual brings into one volume information valuable as a reference source for those persons actively engaged in or planning groundwater monitoring programs at solid waste disposal facilities. It was completed prior to passage of the Resource Conservation and Recovery Act of 1976, which contains major provisions to move the country more rapidly toward environmentally safe solid waste disposal practices. The implications for monitoring activities are clearly great, and this manual should serve as a particularly useful tool as State solid waste agencies proceed to strengthen their land protection programs. The manual is primarily addressed to the supervisory personnel of solid waste regulatory agencies, although its contents can be readily used by engineers in the field.

Generally, this manual includes fundamentals and provides guidance to assist the user in:

(1) Establishing the need for monitoring.

(2) Assigning priorities for facilities to be monitored.

(3) Implementing and directing a cost-effective, ongoing monitoring program responsible to the purposes and data needs established.

Site specificity is recognized throughout the manual and it includes Purposes and Objectives of Monitoring, Monitoring Networks, Monitoring and Well Technology, Indicators of Leachate, Fundamentals of Leachate, Sample Withdrawal, Storage and Preservation, and Analytical Methods.

Article: Sullivan, D. A., and Strauss, J. B. 1981. "Air Monitoring of a Hazardous Waste Site," Management of Uncontrolled Hazardous Waste Sites, Hazardous Materials Control Research Institute, Silver Spring, Md.

Subject: Air Quality Monitoring and Modeling.

Description: Versar Inc., as a contractor to the U. S. Environmental Protection Agency for air quality emergency response, performs ambient monitoring, dispersion modeling, and other support functions as requested by the Division of Stationary Source Enforcement. In this capacity, Versar and GEOMET, Inc., responded to a request to perform ambient air sampling at Rollins Environmental Services' (RES) waste treatment and disposal facility near Baton Rouge, Louisiana. This paper focuses on Versar's approach to the identification and quantification of airborne pollutants from a hazardous waste facility.

Economic Aspects

The economics or socioeconomics to be considered at this point in the remedial site evaluation and investigation must address the impact of the various alternatives on the local community (communities) or the overall region, if appropriate. The EPA has published a monograph (No. 27-Legal Considerations) that addresses this issue, and several related articles appeared in the Proceedings of the Sixth Annual Research Symposium (EPA 600/9-80-011). Reviews are included.

Technical Monograph: USEPA. 1981. "Technical Methods for Investigating Sites Containing Hazardous Substances - Legal Considerations," Technical Monograph No. 27, 28 pp.

Subject: Socioeconomic Aspects.

Description: Legal considerations related to the investigation of sites containing hazardous substances include the right to enter, the scope of inspection activity, confidentiality and secrecy agreements, photography, inspection procedures, and the conditions necessary for obtaining a warrant. The laws and procedures that apply to the considerations mentioned above and others are addressed in this monograph.

Hazardous site inspection and investigation activities are influenced by a variety of legal concerns that must be appreciated from the outset. Although an inspection may be authorized by any number of federal or state statutes, there are overall constitutional, statutory, and evidentiary legal requirements that define the broad procedural limits of each phase of an investigation. An inspector must always be aware that his primary function is to gather accurate data in accordance with the fundamental principles of law. These principles will:

(1) Ensure that the data gathered can be used effectively in enforcement proceedings.

(2) Protect the rights of inspected and third parties and minimize the inspector's potential liability.

(3) Minimize risk to affected third parties.

Article: Taylor, G. C. 1980. "Socioeconomic Analysis of Hazardous Waste Management Alternatives," In Shultz, D., and Black, D. Treatment of Hazardous Waste: Proceedings of the Sixth Annual Research Symposium. EPA-600/9-80-011. U. S. Environmental Protection Agency, Washington, D. C. p. 132.

Subject: Economic Justification.

Description: This paper presents a methodology for analyzing the economic and social effects of alternative approaches to hazardous waste management. The methodology recognizes the role of sociological factors in decisionmaking, and overcomes some of the difficulties that may be encountered if the conventional economic analyses for pollution control is applied to hazardous wastes. The methodology involves the generation of a series of environmental "threat scenarios" that might arise from the use of different hazardous waste management techniques, and utilizes a simple interaction model that links policy, technological, and socioeconomic aspects of waste management alternatives. A key element in the methodology is identification of "parties-at-interest" to the various waste management techniques. By examining how the parties-at-interest are affected by alternative approaches to hazardous waste management, it is possible to make decisions that are based on economics, but which recognize sociological factors including equity and public attitudes towards risk-taking. It is shown that while the methodology simplifies the decisionmaker's

task, the ultimate decision will depend on the degree of risk aversion favored, and may require subjective judgments.

Use of the methodology is illustrated by some results from a case study of hazardous waste management alternatives for Oregon.

Article: Anderson, R. C., and Dower, R. C. 1980. "The Use of Cost-Benefit Analysis for Hazardous Waste Management," In Shultz, D., and Black, D. Treatment of Hazardous Waste: Proceedings of the Sixth Annual Research Symposium. EPA-600/9-80-011. U. S. Environmental Protection Agency, Washington, D. C. p. 149.

Subject: Economic Justification.

Description: Hazardous waste management poses special problems to decisionmakers interested in structuring an effective and efficient regulatory policy. This paper addresses the applicability of cost-benefit techniques as tools for assisting regulatory policy development for hazardous wastes. The underlying assumption is that regulatory strategies based on considerations of costs and benefits will improve resource allocation.

The paper is divided into two main sections. First, there is an outline of the important characteristics of cost-benefit analysis and its variations; most notably risk-benefit and cost-effective analyses. Stress is placed on some obvious difficulties in applying these techniques to issues of environmental, health, and safety risks, such as uncertainty over health effects and economic costs, questions of inter- and intra-generational equity, and the proper value for human life. Where possible, these important issues are illustrated with examples from actual federal rulemaking processes. Undoubtedly, the same issues will arise in using cost-benefit techniques for hazardous waste management.

Second, some tentative observations are offered on current command and control approaches to hazardous waste management and the potential for improvement that could be achieved from viewing regulatory alternatives in a cost-benefit perspective. For example, a dearth of information on the location and hazard characteristics of many sites and the lack of incentives for private provision of this information may severely limit the effectiveness of the regulatory approach. Creating incentives to reveal information and to reduce the flow of hazardous wastes into the environment should improve the cost-effectiveness of hazardous waste management programs.

Other References

The following references contain information related to remedial site investigations and may be of value to some readers.

Bredehoeft, J. D., and Pinder, G. F. 1972. "Application of Transport Equations to Groundwater Systems," in Cook, T. D. (ed.) Underground Waste Management and Environmental Implications. Am. Ass. Pet. Geo. Tulsa, OK. p. 191.

Ferris, J. G. 1972. "Response of Hydrologic Systems to Waste Storage," in Cook, T. D. (ed.) Underground Waste Management and Environmental Implications. Am. Ass. of Pet. Geo. Tulsa, OK. p. 126.

Talbot, J. S. 1972. "Requirements for the Monitoring of Industrial Deep-Well Waste-Disposal System," in Cook, T. D. (ed.) Underground Waste Management and Environmental Implications. Am. Ass. of Pet. Geo. Tulsa, OK. p. 85.

Robertson, J. M., Toussaint, C. R., and Jorque, M. A. 1974. Organic Compounds Entering Groundwater From a Landfill. EPA 660/2-74-077. U. S. EPA, Washington, D. C. 47 pp.

Clark, Thomas P. 1975. "Survey of Groundwater Protection Methods for Illinois Landfills." Groundwater, Vol. 13, No. 4, p. 321.

Stollar, R. L., and Roub, R. 1975. "Earth Resistivity Surveys--A Method for Defining Groundwater Contamination." Groundwater, Vol. 13, No. 2, p. 145.

Todd, D. K. 1980. Groundwater Hydrology (2nd ed.). John Wiley & Sons. New York, NY. 535 pp.

Benson, R., Glaccum, R., and Beam, P. 1981. Minimizing Cost and Risk in Hazardous Waste Site Investigations Using Geophysics, Management of Uncontrolled Hazardous Waste Sites, U. S. Environmental Protection Agency and American Society of Civil Engineers, pp. 84-88.

Hagger, C., and Caly. P. F. 1981. Hydrogeological Investigation of an Uncontrolled Hazardous Waste Site pp. 45-51 in National Conference on Management of Uncontrolled Hazardous Waste Sites. Hazardous Material Control Research Institute, Silver Springs, MD. 420 pp.

Hoeks, J. 1981. "Analytical Solutions For Transport of Conservative and Nonconservative Contaminants in Groundwater Systems." Water, Air, and Soil Poll., Vol. 16, p. 339.

McKown, C L., and Sandness, G. A. 1981. Computer-Enhanced Geophysical Survey Techniques for Exploration of Hazardous Waste Sites, Management of Uncontrolled Hazardous Waste Sites, U. S. Environmental Protection Agency and American Society of Civil Engineers, pp. 300-305.

Peters, J. A., Tackett, K. M., and Eimutis, E. C. 1981. Measurement of Fugitive Hydrocarbon Emissions from a Chemical Waste Disposal

Area, Management of Uncontrolled Hazardous Waste Sites, U. S. Environmental Protection Agency and American Society of Civil Engineers, pp. 123-128.

Scalf, M. R., McNabb, J. F., Dunlap, W. J., Cosby, R. L., and Fryberger, J. S. 1981. Manual for Groundwater Quality Sampling Procedures, USEPA, Ada, Okla.

Sisk, S. W. 1981. NEIC Manual for Groundwater/Subsurface Investigations at Hazardous Waste Site, EPA-330/9-81-002, 72 pp.

Spear, R., and Franconeri, P. 1981. Installing Groundwater Monitoring Wells at Hazardous Waste Site. pp. 89-95. in National Conference on Management of Uncontrolled Hazardous Waste Sites. Hazardous Material Control Resource Institute. Silver Springs, MD. 420 pp.

Chemical Hazards Response Information System (CHRIS). Department of Transportation - U.S. Coast Guard, 1978.

MANUAL 1 COMDTINST M16465.11 A CONDENSED GUIDE TO CHEMICAL HAZARDS

Intended for use by response personnel who may be the first to arrive at the site of an accidental discharge or fire to assess the dangers and consider the appropriate large-scale response necessary to safeguard life and property (contains 1000 chemicals).

MANUAL 2 COMDTINST M16465.12 HAZARDOUS CHEMICAL DATA

This manual is the cornerstone of CHRIS. It lists the specific chemical, physical, and biological data for about 1000 chemicals needed for the preparation and use of other components of the system. It is intended for use primarily by the On-Scene Coordinator (OSC) and by regional and National Response Centers for devising, evaluating, and carrying out response plans.

MANUAL 3 COMDTINST M16465.13 HAZARD ASSESSMENT HANDBOOK

Describes procedures to be used for estimating the quantities of a hazardous chemical discharge onto a navigable waterway during shipment. It also describes how to estimate its concentration in air and water as a function of time and distance from the discharge. Methods for predicting the resulting toxicity, fire, and explosion effects are also described.

MANUAL 4 COMDTINST M16465.14 RESPONSE METHODS HANDBOOK

Describes cautionary and corrective response methods for reducing and eliminating hazards that result from chemical discharge. Written specifically for Coast Guard personnel with training or experience in pollution response.

PART IV: IDENTIFICATION AND SELECTION OF REMEDIAL SYSTEMS

Introduction

This part contains information on the flow of contaminants from a land disposal site (see Figure 4-1), and a hierarchical approach for the development of preliminary remedial action plans for specific sites, site-specific considerations, site parameters, and sources of information.

Flow of Contaminants

Land disposal waste materials are subject to various transport processes which may lead to environmental contamination. These transport processes involve an initial transformation to a more mobile phase, usually by solubilization, volatilization, or a chemical or biochemical reaction that forms soluble or gaseous reaction products. Figure 4-1 is a flow diagram of the initial mobilization processes. The chemical and biochemical reactions have, on occasion, resulted in explosions, and the resulting fires have released particulates and gases to the atmosphere. Figure 4-1 clearly illustrates that wastes have the potential to be mobilized in any phase. Waste materials may migrate outside a disposal site and pollute the groundwater and surface water as well as the aeolian, terrestrial, and benthic environments. Figure 4-2 depicts the flow of pollutants from land-disposed waste in the environment to various receptors. Polluting disposal sites may contaminate drinking water wells and produce toxic or deadly fumes or contaminate surface water by leaching. Additionally, contamination of aquatic food chains may develop from biological uptake of wastes by benthic (bottom dwelling) organisms. The development of an effective remedial action plan for a polluting waste disposal site must take into account all of the pathways involved in the transport of contaminants through the environment and to receptors.

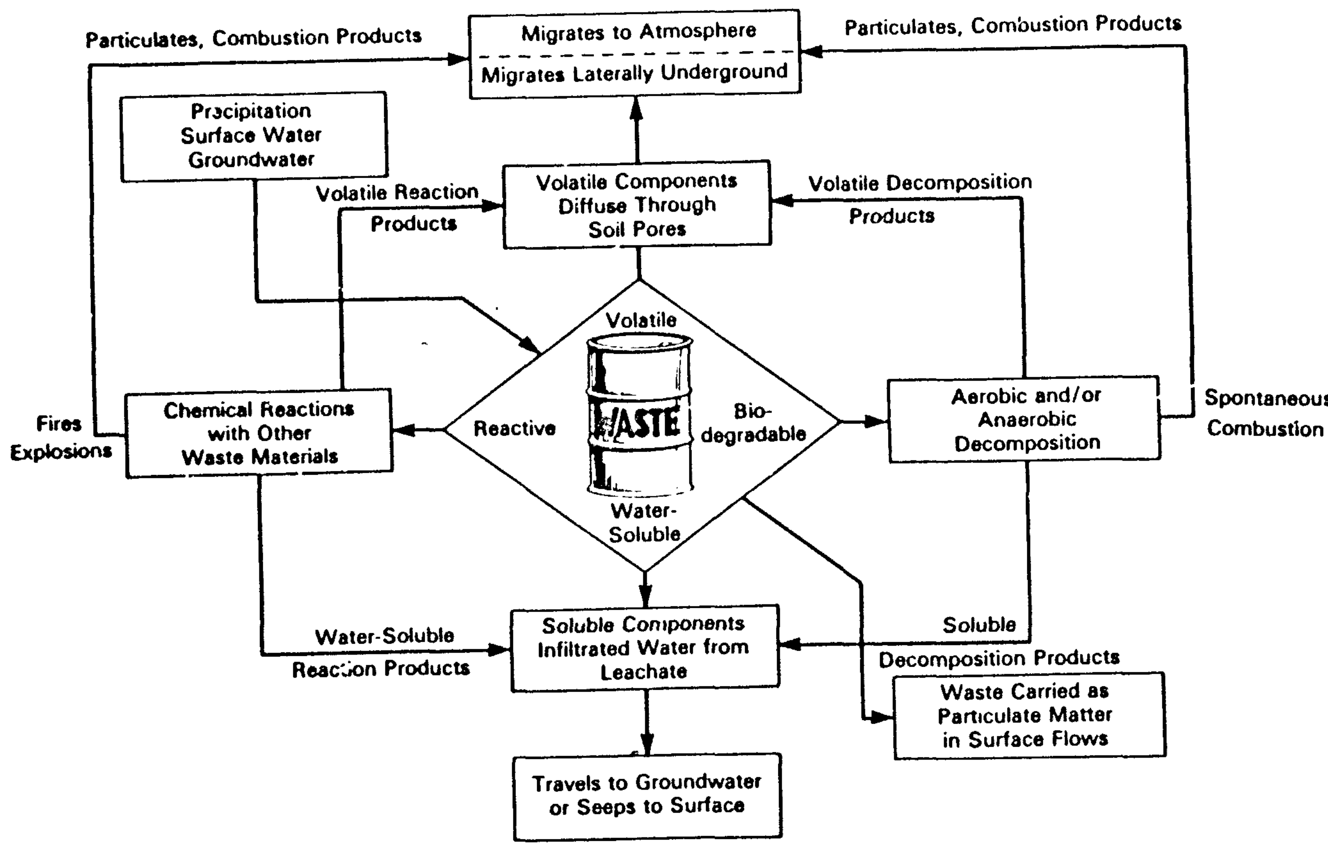


Figure 4-1. Initial Transport Processes at Waste Disposal Sites (From EPA "Handbook for Remedial Action at Waste Disposal Sites," EPA-625/6-82-006, June 1982)

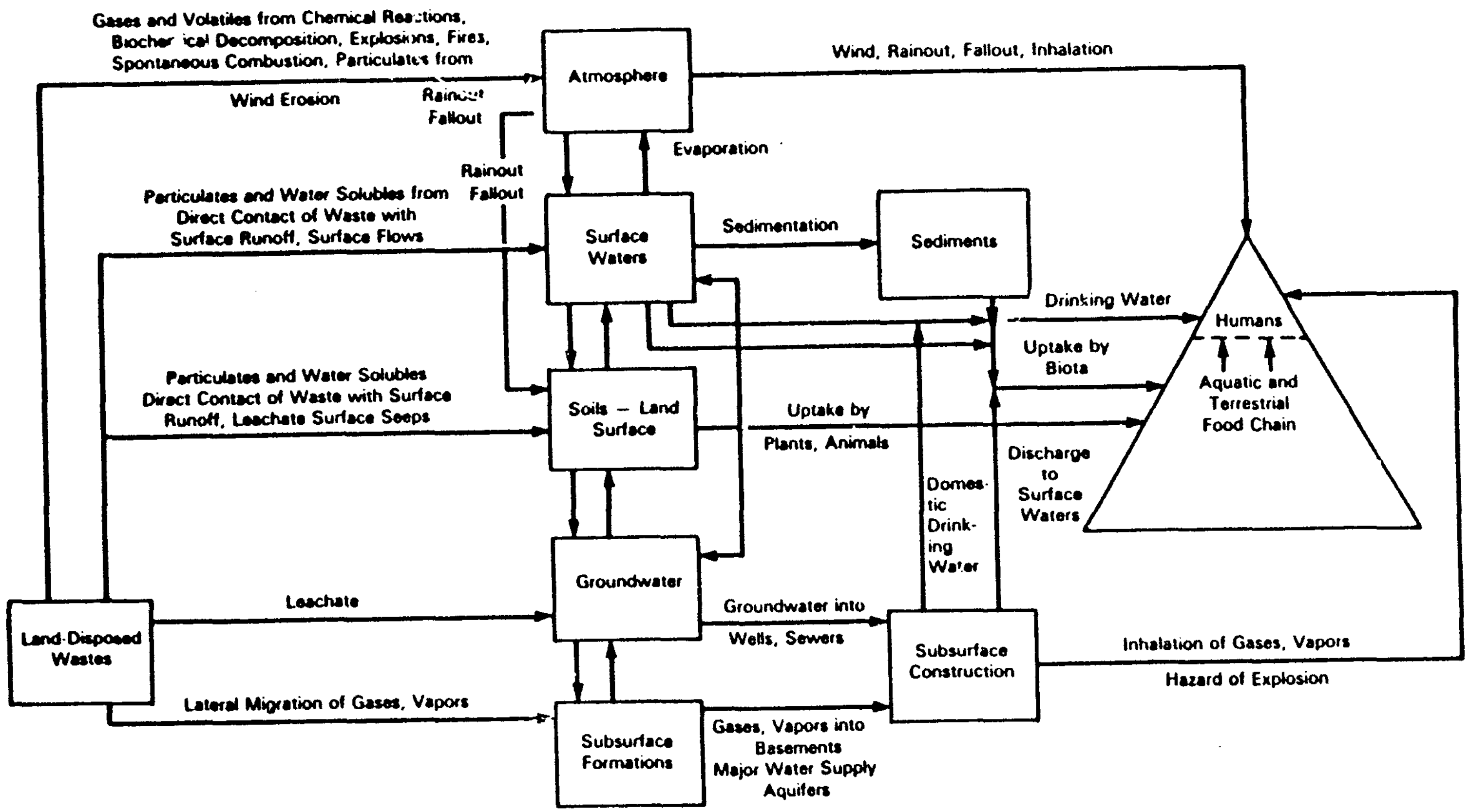


Figure 4-2. Flow of Land-Disposed Waste Contaminants Through the Environment (From EPA "Handbook for Remedial Action at Waste Disposal Sites," EPA-625/6-82-006, June 1982)

Hierarchical Approach

Once the problem has been defined, the site characterized, and an assessment made of the compliance status with respect to the various applicable environmental regulations, an organized, logical hierarchical approach is required for both the generation of control strategies and the screening of these strategies with respect to a set of criteria. The recommended approach is illustrated in Figure 4-3. Reviews of three documents containing excellent background data are included. The first document was prepared by WES for DARCOM and the second was prepared by J. R. Band Associates for EPA. The essential elements of the NCP which impact strongly on selections of remedial systems have also been abstracted for this section.

Report: USATHAMA. 1981. "Contamination Control Strategies for Rocky Mountain Arsenal." U. S. Army Toxic and Hazardous Materials Agency, Aberdeen Proving Ground, Md.

Subject: Hierarchical Approach - Control Strategies.

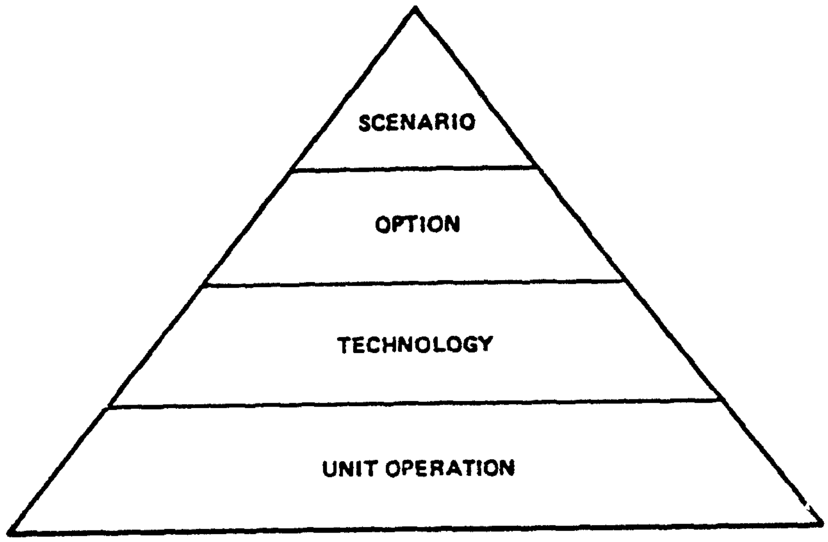
Description: This report summarizes and describes the historical contamination problems at Rocky Mountain Arsenal (RMA), a methodology used to develop alternative control strategies, various alternatives that address control and elimination of the contamination problems, and a recommended problem definition and technology development program needed to support the detailed evaluation of selected alternatives. There is also a summary of historical reports that were used for background and reference during the study, additional study requirements to fill essential problem definition and technology development data gaps, and several follow-on study efforts.

Report: USEPA. 1982. "Handbook for Remedial Action at Waste Disposal Sites," USEPA EPA-625/6-82-006.

Subject: Remedial Actions.

Description: This report develops remedial action plans for the cleanup of polluting waste disposal sites. It is geared primarily for technical personnel in Federal, state, regional, and municipal agencies involved in the cleanup of hazardous waste disposal sites, industrial surface impoundments, and municipal, industrial, and combined landfills.

SCHEME



- o SCHEME - Systematic Plan of Action.
- o SCENARIO - Outline Plan for One or More Source Locations.
- o OPTION - Choice to Control/Treat/Store/Dispose/Do Nothing.
- o TECHNOLOGY - Applied Scientific Process.
- o UNIT OPERATION - Functional Method for Achieving Practical Application of Technology

Figure 4-3. Scheme hierarchy (from "Contamination Control Strategies for Rocky Mountain Arsenal," Interim Report, USATHAMA)

It summarizes the flow of contaminants from a land disposal site, the remedial actions available for site cleanup, and a methodology by which a preliminary remedial action plan can be developed for a specific site. The report shows the pollutant pathways involved in a waste disposal site; the remedial actions and how they apply to site characteristics such as climate, hydrology, type of waste; a generalized approach to the process of selecting remedial actions for a polluting site; and an example of the selection of remedial actions for a specific site.

Additional detailed information is provided on remedial actions applicable to surface flow control, groundwater control, leachate control, gas migration control, direct treatment of land disposed wastes, cleanup of contaminated sewers and water pipes, and cleanup of contaminated sediments. Each section gives information on each remedial option with respect to:

(1) General description.

(2) Applications.

(3) Design, construction, and/or operating considerations.

(4) Advantages.

(5) Disadvantages.

(6) Installation and operating costs.

There is auxiliary information on wastewater treatment unit operations and costs, monitoring methodology, safety and health considerations, and cost update indicies.

Report: National Contingency Plan (NCP). 1982. EPA, Washington, D. C.

Subject: NCP, Remedial Actions.

Description: Superfund requires the NCP to be revised to reflect and effectuate the responsibilities and powers created by Superfund (Section 105). The revision of the NCP includes a section of the plan to be known as the National Hazardous Substance Response Plan which will establish procedures and standards for responding to releases of hazardous substances, pollutants, and contaminants and will include at a minimum:

(1) Methods for discovering and investigating facilities at which hazardous substances have been disposed of or otherwise come to be located.

(2) Methods of evaluating, including analyses of relative costs, and remedying any releases or threats of release from facilities which pose substantial danger to the public health or the environment.

(3) Methods and criteria for determining the appropriate extent of removal, remedy, and other measures authorized by CERCLA.

(4) Appropriate roles and responsibilities for the Federal, state, and local governments and for interstate and non-governmental entities in effectuating the plan.

(5) Provision for identification, procurement, maintenance, and storage of response equipment and supplies.

(6) A method for assignment of responsibility for reporting the existence of such facilities which may be located on Federally owned or controlled properties and any releases of hazardous substances from such facilities.

(7) Means of ensuring that remedial action measures are cost-effective over the period of potential exposure to the hazardous substances or contaminated materials.

(8) Criteria for determining priorities among releases or threatened releases throughout the United States for the purpose of taking remedial action and, to the extent practicable, taking into account the potential urgency of such action, for the purpose of taking removal action.

(9) A list of national priorities among the known releases or threatened releases throughout the United States based upon the criteria established in accord with Section 105(8)(A).

A postclosure liability fund has been established to provide $200 million to monitor legal dumps and make sure they cause no damage once they are closed.

The Agency for Toxic Substances and Disease Registry was created within the Public Health Service for the purpose of studying health effects and the registration of toxic waste victims.

The President has the responsibility for implementing the legislation. The primary agencies to which the President has delegated responsibility for carrying out the function are:

(1) The EPA will manage the fund and implement response and remedial action associated with hazardous sites.

(2) The EPA and the Coast Guard will maintain their present distribution of responsibility for hazardous substance spills.

(3) The Treasury Department will collect the taxes and enforce the tax structure.

The EPA and the U. S. Army Corps of Engineers have signed an interagency agreement. The Corps will provide management and technical assistance for remedial actions that may be assigned by EPA and accepted by the Corps.

Site-Specific Considerations

Of the documents reviewed, two were selected for this section. These were a technical monograph prepared by EPA specifically for Superfund activities and a technical journal article.

Technical Monograph: USEPA. 1981. "Technical Methods for Investigating Sites Containing Hazardous Substances - Purposes and Objectives of Sampling," Technical Monograph No. 15, 11 pp.

Subject: Site-Specific Considerations.

Description: Sampling is a useful tool for gauging the existence, type, and extent of contamination of the environment by a hazardous substance. The data derived from the analysis of samples are evidence for litigation. This monograph specifies the potential purposes and objectives of a sampling program and explains the utility and limitations of the analytical data obtained.

Currently there are few publications providing guidance specifically directed to sampling at hazardous substance sites. The publications most directly applicable to sampling at hazardous substance sites include the following:

(1) "Enforcement Considerations for Evaluations of Uncontrolled Hazardous Waste Sites by Contractors" (EPA, 1980)

(2) Samplers and Sampling Procedures for Hazardous Waste Streams (EPA, 1980)

(3) Procedure Manual for Groundwater Monitoring at Solid Waste Disposal Facilities (EPA, 1977)

(4) Field Monitoring and Analysis of Hazardous Materials (EPA, 1980)

Survey and Case Studies: Neely, N., Gillespie, D., Schauf, F., and Walsh, J. 1981. "Remedial Actions at Hazardous Waste Sites: Survey and Case Studies," USEPA EPA-430/9-81-005, 230 pp.

Subject: Site-Specific Considerations.

Description: With the passage of Superfund legislation providing for the cleanup of environmental hazards at uncontrolled waste disposal sites, information was needed on the types of remedial actions that had been implemented to date, as well as their effectiveness and cost. The report provides this information by presenting the results of a nationwide survey of 169 such remedial action sites. More specific information on nine of these sites is provided in the form of detailed case studies, also contained herein.

Site Parameters

Reviews of two books published by ASTM, a report by EPA, and four articles are included in this section.

Book: ASTM. 1976. STP-607-Biological Monitoring of Water and Effluent Quality, American Society for Testing and Materials, Philadelphia, PA. 242 pp.

Subject: Site Parameters - Biological Monitoring.

Description: Seventeen comprehensive papers assess current state of the art and evaluate present and future needs for biological monitoring.

Book: ASTM. 1979. STP-695-Native Aquatic Bacteria: Enumeration, Activity, and Ecology, American Society for Testing and Materials, Philadelphia, PA. 219 pp.

Subject: Site Parameters - Aquatic Bacteria.

Description: A broad discussion of the theoretical basis and practical problems of current methods in aquatic microbiology. The first two sections address the problem of how to arrive at an accurate enumeration of the bacteria present in aquatic environments. The third section describes and evaluates methods for measuring specific metabolic activities of bacterial populations in aquatic environments. This book will be of value to anyone involved in comparing, evaluating, and selecting methods for the study of native aquatic bacteria.

Report: Hughes, G. M., Landon, R. A., and Farvolden, R. N. 1971. Hydrogeology of Solid Waste Disposal Sites in Northeastern Illinois. EPA-SW-12d, U. S. Environmental Protection Agency, Washington, D. C. 154 pp.

Subject: Site Parameters.

Description: Hydrogeologic and water quality studies of five landfills in northeastern Illinois were carried out over a four-year period. The distribution and concentration of dissolved solids in the vicinity of four of these landfills were found to be controlled by the configuration of the groundwater flow system. The major factors influencing the attenuation of the dissolved solids after they have left the landfill appear to be the particle size of the earth materials through which these dissolved solids move and the distance that they move.

Precipitation in northeastern Illinois is adequate to infiltrate a completed landfill and to leach the refuse. Where the

natural environment is not capable of containing or assimilating this leachate, the landfilling operation can probably be made safe by lining the disposal site, by collecting and treating the leachate, or by other relatively simple engineering procedures.

Article: Galley, J. E. 1972. "Geologic Framework for Successful Underground Waste Management," in Cook, T. D. (ed.) Underground Waste Management and Environmental Implications, Am. Ass. Pet. Geo. Tulsa, OK. 119 p.

Subject: Site Parameters.

Description: Insoluble solid wastes can be buried at shallow depths in locations where they are safe from exhumation. If any parts are soluble, the solution must be managed as with any similar liquid waste. Programs for the management of waste liquids must be tailored to the chemical and physical characteristics of the liquids.

Requisites for successful underground management of liquid wastes include: (1) porous and permeable reservoir rocks, in which the storage space may be caverns, intergranular pores, or fracture crevices; (2) impermeable seals to prevent escape of fluid wastes; (3) adequate understanding of hydrologic parameters and planning to prevent undesirable migration of fluids; and (4) compatibility between waste materials and the reservoir rocks and their natural fluids.

Layered sedimentary rocks, rather than igneous or metamorphic rocks, provide the most suitable reservoir space, for both geologic and hydrologic reasons. If the wastes are hazardous to the biosphere, objective reservoir formations must be deep enough to provide permanent protection to groundwater aquifers.

The site must be reasonably stable seismically and not actively moving along, or broken by, faults.

Choice of a suitable underground disposal site can be made only after a thorough investigation of available subsurface data, supplemented by drilling and various other processes of subsurface exploration if sufficient data are not already available. Preliminary investigations and later subsurface operations will be expensive, but they cannot be avoided. Public insistence on an end to pollution must be accompanied by public understanding that a clean environment can be purchased only by higher taxes, if government managed, or by higher prices for consumer goods, if industry managed, plus individual awareness and practices.

As waste management costs rise, it will become more economical to convert wastes into usable products, in effect eliminating, rather than managing, wastes.

Article: Remason, I., Fungaroli, A. A., and Lawrence, A. W. 1968. "Water Movement in an Unsaturated Sanitary Landfill," ASCE, Vol. 94, No. SA 2, 307 pp.

Subject: Site Parameters.

Description: This study has been restricted to the consideration of a sanitary landfill as an isolated leachate generator. Actually, its significance as a contamination source depends upon its location in a geologic-hydrologic system. The local geology and hydrology may be such that the leachate will enter important aquifers or streams. On the other hand, the leachate may move into systems where its significance is negligible. This, the moisture routing through the soil cover and fill, is only an initial step in the hydrologic analysis of the total system.

Article: Cartwright, K., Griffin, R. A., and Gilkeson, R. H. 1977. "Migration of Landfill Leachate through Glacial Tills," Groundwater, Vol. 15, No. 4, 294 pp.

Subject: Site Parameters.

Description: To evaluate the potential of natural clay minerals for attenuating and preventing the pollution of water resources by landfill leachates, leachate was collected by anaerobic techniques from the 15-year-old Du Page County sanitary landfill near Chicago, Illinois, and was passed through 44 laboratory columns that contained various mixtures of calcium-saturated clays and washed quartz sand.

Results of the laboratory data were compared with field data from the Du Page County sanitary landfill and from other existing landfills where detailed data are available. The field data show a "hardness halo" corresponding to the Ca release in the column studies. The relative attenuation rates of some of the ions were also confirmed by the field data. The change in hydraulic conductivity was not as clearly shown.

Ion exchange capacity, hydraulic conductivity, and buffering capacity of the earth materials were all shown to be important in assessing the potential of landfills for water pollution.

Article: Whitmore, F. C. 1980. "Windmills, Incinerators and Siting," In Shultz, D., and Black, D. Treatment of Hazardous Waste: Proceedings of the Sixth Annual Research Symposium. EPA-600/9-80-011. U. S. Environmental Protection Agency, Washington, D. C. 112 pp.

Subject: Site Parameters.

Description: The public reaction to proposals for the siting of hazardous waste disposal facilities results largely from fear and

from distrust of technologists. Several case histories are presented with inferences drawn as to possible future actions to reduce the problem. Although a prescription for successful siting of a hazardous waste disposal facility is not offered, the author is able to use personal experience to describe the pitfalls into which others might stray.

Sources of Information

The EPA has a series of four technical monographs on site investigation that are best classified as general information sources. Reviews of these are included. Reviews of three books prepared by ASTM and a technical report by EPA are also included. The EPA monographs cover:

a. Team Organization.

b. Site Inspections.

c. Preliminary Assessment.

d. Documentation Requirements.

The three books published by the ASTM deal with data base management and data interpretation. One technical report review is included which deals with the quality control aspects of managing analytical chemistry data.

Technical Monograph: USEPA. 1981. "Technical Methods for Investigating Sites Containing Hazardous Substances - Organization of the Field Team," Technical Monograph No. 7, 11 pp.

Subject: Team Organization.

Description: The primary function of the field investigation team is to gather available information from hazardous substance sites. This monograph describes components, duties, and sizes of the field team that are prescribed in order to safely meet the stated goals of the investigation.

Once the strategy and objectives of the work plan have been developed, a team must be organized to implement the plan. The specific techniques described in the work plan are likely to include: environmental sampling, sampling of hazardous substances, drilling operations, mapping, hazardous substance inventory, etc.

Hazardous substance sites present many hazards, physical conditions, and situations that require a wide variety of expertise and scientific support to ensure safe entry and data collection. It is impractical to design a standard site entry team

given the significant difference among sites. Therefore, each site requires a team tailored to the potential hazards and objectives of that site. The field investigation team will likely consist of individuals with various technical backgrounds, i.e., chemist, engineer, hydrogeologist, who will also fill field positions such as site safety officer or command post supervisor.

A team entering a hazardous substance site is organized for mutual support and safety. Hazardous site investigations require a complete respect for safety by all team members to prevent injury or loss of life.

Technical Monograph: USEPA. 1981. "Technical Methods for Investigating Sites Containing Hazardous Substances - Site Investigations," Technical Monograph No. 5, 6 pp.

Subject: Site Inspections.

Description: Hazardous substance sites may require visual inspection to supplement the information gained from preliminary assessment. This appraisal further characterizes the site in terms of its environmental pollution and hazard potential. Since site contact is required, it is the first investigative procedure requiring safety considerations. This monograph details the types of information sought in a proper site inspection and presents the conclusions that normally result.

One of the possible conclusions of a preliminary site assessment is that a site inspection is required.

Site inspections characterize a hazardous substance site using the same generic information used in preliminary assessment. The term site inspection implies a visual appraisal of site conditions, but also includes personal interviews with individuals familar with the site history.

The goal of a site inspection could be one or more of the following:

(1) To confirm preliminary assessment data that are otherwise poorly substantiated.

(2) To obtain data unavailable during the preliminary assessment.

(3) To update site conditions if there are indications that undocumented changes may have occurred at the site.

(4) To obtain data necessary to plan a field investigation. Such information would include location of access routes, sampling points, site organization, etc.

Technical Monograph: USEPA. 1981. "Technical Methods for Investigating Sites Containing Hazardous Substances - Preliminary Assessments," Technical Monograph No. 4, 8 pp.

Subject: Preliminary Assessments.

Description: Following site discovery and the initial consideration for the need of emergency action, a more thorough evaluation of site history and conditions is required for regulatory agency decisions. This review should normally consist of two elements: preliminary assessment and a field inspection (if required). The former occurs entirely offsite, while the latter requires site entry.

The purpose of this monograph is to detail the work required to accomplish a preliminary assessment. With the information gathered from preliminary assessment, emergency action needs can be addressed, the need for further investigation or remedial work can be assessed and sites ranked accordingly, or a site may be dismissed as requiring no further action. The knowledge resulting from preliminary assessment allows for more accurate safety planning if field work is required and provides a cost-effective method that minimizes the unnecessary commitment of expensive resources. This last benefit alone supports the logic of doing preliminary assessment prior to site inspection or field investigation.

Technical Monograph: USEPA. 1981. "Technical Methods for Investigating Sites Containing Hazardous Substances - Documentation Requirements," Technical Monograph No. 26, 7 pp.

Subject: Documentation Requirements.

Description: Information gathered during a field operation must be sufficiently accurate, detailed, and retrievable so that the goals of the investigation can be met. The information is usually summarized in a report along with recommended follow-up actions. This monograph outlines the requirements and procedures usually employed to ensure the future usefulness of the information gathered.

Many investigations of sites containing hazardous substances will eventually support litigation under the enforcement provision of the Resource Conservation and Recovery Act of 1976 (RCRA Public Law 94-580) and the Comprehensive Environmental Response, Compensation, and Liability Act (Superfund, Public Law 96-510). All information, data, samples, and documents must be treated as evidence and must be retrievable when the project is completed.

Book: ASTM. 1978. STP-652-Biolcgical Data in Water Pollution Assessment: Quantitative and Statistical Analyses, American Society for Testing and Materials, Philadelphia, PA. 193 pp.

Subject: Data Base Management.

Description: The book includes useful basic information on quantitative and statistical approaches in assessing the impact of pollutants on aquatic life. Twelve papers cover statistical design of environmental studies, use of multivariate analyses, ranking methods, diversity indices, and factor analyses.

Report: EPA. 1979. "Handbook for Analytical Quality Control in Water and Wastewater Laboratories," EPA-600/4-79-019, U.S. Environmental Protection Agency, Washington, D. C. 120 pp.

Subject: Data Base Management - Analytical Quality Control.

Description: This handbook is addressed to laboratory directors, leaders of field investigations, and other personnel who bear responsibility for water and wastewater data. Subject matter of the handbook is concerned primarily with quality control (QC) for chemical and biological tests and measurements. Chapters are also included on QC aspects of sampling, microbiology, biology, radiochemistry, and safety as they relate to water and wastewater pollution control. Sufficient information is offered to allow the reader to inaugurate or reinforce programs of analytical QC that emphasize early recognition, prevention, and correction of factors leading to breakdowns in the validity of water and wastewater pollution control data.

Other References

ASTM. 1969. STP-468-A Manual on Methods for Retrieving and Correlating Technical Data, American Society for Testing and Materials, Philadelphia, PA. 74 pp.

Barnes, I. 1972. "Water-Mineral Reactions Related to Potential Fluid-Injection Problems" in Cook, T. D. (ed.) Underground Waste Management and Environmental Implications. Am. Ass. of Pet. Geo. Tulsa, OK. p. 294.

Ehrlich, G. G. 1972. "Role of Biota in Underground Waste Injection and Storage" in Cook, T. D. (ed.) Underground Waste Management and Environmental Implications. Am. Ass. of Pet. Geo. Tulsa, OK. p. 298.

Hanshaw, Bruce B. 1972. "Natural-Membrane Phenomena and Subsurface Waste Emplacement" in Cook, T. D. (ed.) Underground Waste Management and Environmental Implications. Am. Ass. of Pet. Geo. Tulsa, OK. p. 308.

Hower, W. F., Lasater, R. M., and Mihram, R. G. 1972. "Compatibility of Injection Fluids with Reservoir Components" in Cook, T. D. (ed.) Underground Waste Management and Environmental Implications. Am. Ass. of Pet. Geo. Tulsa, OK. p. 287.

ASTM. 1976. STP-15D-Manual on Presentation of Data and Control Chart Analysis, American Society for Testing and Materials, Philadelphia, PA. 186 pp.

Griffin, R. A., and Shimp, N. F. 1976. "Effect of pH on Exchange-Adsorption or Precipitation of Lead from Landfill Leachates by Clay Minerals." Env. Sci. and Tech. Vol. 10, No. 13, p. 1256.

Griffin, R. A., Shimp, N. F., Steele, J. D., Ruch, R. R., White, W. A., and Hughes, G. M. 1976. "Attenuation of Pollutants in Municipal Landfill Leachate by Passage through Clay." Env. Sci. and Tech. Vol. 10, No. 13, p. 1262.

Jennings, A. A., Tirsch, F. S., and Adrian, D. D. 1978. "Soil Attenuative Capacity and Transport Potential of Solid Waste Leachates." In 33rd Annual Purdue Industrial Waste Conf., Purdue Univ., West Lafayette, IN, May 1978.

ASTM. 1979. STP-673-Methodology for Biomass Determinations and Microbial Activities in Sediments, American Society for Testing and Materials, Philadelphia, PA. 199 pp.

Pintenich, J. L., Hines, J. M., Corn, M. R., and Ziegler, F. G., 1981. "Characterization, Impact Assessment, and Closure Requirements for a Copper Residue Disposal Site, Management of Uncontrolled Hazardous Waste Sites," U. S. Environmental Protection Agency and American Society of Civil Engineers, pp. 70–78.

PART V: SITE REMEDIAL TECHNIQUES

Introduction

Hazardous waste disposal site remedial techniques may include: (a) control of surface water, or runoff, by constructing diversion structures or liners and covers, by surface grading, and by collecting runoff, as in surface impoundments; (b) control of groundwater movement or contamination by subsurface barriers, such as the slurry trench, grout curtain, underdrains, and pump wells; (c) control of leachate; (d) control of gas migration; and (e) control of windblown particulates through physical, chemical, and vegetative stabilization of disposal site soils.

Site remedial techniques are usually undertaken where the volume of or hazard associated with the waste makes it impractical or impossible to move the contaminant to a secure landfill site or to treat the waste or contaminated material onsite. In some cases, portions of waste materials have been removed, but the residual contamination in soil and groundwater must be contained onsite. Site remedial techniques generally are used for onsite containment, with natural processes such as normal flushing of an aquifer or natural biological degradation accounting for the actual destruction of contaminants. Site techniques are often implemented along with treatment systems to minimize the volume of material requiring treatment. For example, if leakage or leachate from the site must be treated, control of runon and percolation through the site can reduce the volume of water that must be collected and treated.

Surface Water Control

There is a wealth of information on this subject, some of a recent vintage written specifically to address the problems at disposal sites, some from general engineering and agricultural fields, and some that would date almost to antiquity. Principal techniques for surface water control are:

a. Runon diversion.

b. Surface grading.

c. Cover construction.

d. Runoff collection.

The best discussion of the applications of the above techniques to surface water controls appears in Chapter 3 of the "Manual for Remedial Options At Waste Disposal Sites" and the "Guidance Manual for Minimizing Pollution from Waste Disposal Sites." An abstract of the latter follows. In 1980, EPA conducted a survey of remedial measures applied to uncontrolled hazardous waste disposal sites, and an abstract of the report on this effort is included.

Report: Tolman, A. L., et al. "Guidance Manual for Minimizing Pollution from Waste Disposal Sites," EPA-600/2-78-142, U. S. Environmental Protection Agency Solid and Hazardous Waste Research Div. Cincinnati, OH. 1978.

Subject: Remedial techniques.

Description: This report contains an indepth study of the remedial techniques that may be applied at uncontrolled hazardous waste sites and covers a large percentage of the technical aspects of the problem.

Report: Neely, Nancy S., et al., "Remedial Actions at Uncontrolled Hazardous Waste Sites," presented at EPA 7th Annual Research Sym, Philadelphia, Mar 16-18, 1981, Vol. 2, p. 312.

Subject: Surface/Groundwater control.

Description: Survey Report: During the summer of 1980, a nationwide survey was conducted to determine the status of remedial measures applied to uncontrolled hazardous waste disposal sites. Remedial actions were found to have been implemented at drum storage areas, incinerators, and injection wells, but most frequently at landfills, dumps, and surface impoundments. Groundwater was identified as the medium most commonly affected, followed by surface waters. Mitigating activities usually consisted of waste containment and/or removal.

Groundwater Control

Contamination of groundwater is a common problem at disposal sites, and it can be handled in one of three ways: (a) installation of

facilities and/or adapting management strategies to reduce or eliminate groundwater migration from the site, (b) diversion of groundwater so that the opportunity for contact with the waste is substantially reduced or eliminated, (c) treatment of contaminated groundwater for release to surface waters or aquifers.

Some of the controls for groundwaters are:

a. Slurry trench walls.

b. Grout curtains.

c. Sheet pilings.

d. Membranes and synthetic sheet curtains.

e. Liners (membranes, etc.)

f. Hydraulic techniques (including pumping).

g. French drains.

h. Underdrains.

Chapter 4 of the handbook entitled "Remedial Action at Disposal Sites" and Chapter 5 of the draft EM prepared as a companion document to this bibliography both contain excellent summaries of the application on these techniques. The references at the end of the chapter offer additional detail on the techniques listed. Abstracts of four recent articles are included.

Article: Cointreau, S. J. 1979. "Reclamation of Solid Waste Disposal Areas." Proceedings of the ASCE Environmental Engineering National Conference, San Francisco, CA.

Subject: Groundwater control.

Description: ABSTRACT: Techniques for reducing groundwater contamination at existing solid waste disposal sites are described. The reclamation techniques include: capping, revegetation, bottom sealing, compaction, surface grading, surface drainage, harrowing, adjusting of pH, nutrient addition, wetting, chemical treatment, slurry trench construction, grout cutoff, the use of wellpoint systems and infiltration galleries, and grout plugging.

Article: Canter, L. 1980. "Ground Water Pollution Control." National Center for Ground Water Research, School of Civil Engineering, University of Oklahoma, Norman, OK.

Subject: Groundwater control.

Description: ABSTRACT: The principles of ground water pollution source control can be divided into three categories. One is to reduce the source potential by minimizing the material to be discarded in disposal wells or pits or ponds. Another is to select disposal sites, or locate various activities, so as to optimize the natural ability of the subsurface environment to remove pollutant materials and preclude ground water contamination. The third category involves building into planned activities certain man-made control options. The majority of this paper deals with controlling pollution sources through application of pretreatment measures for hazardous wastes; site selection techniques for injection wells, sanitary landfills, and chemical landfills; design procedures for i..ection wells, sanitary landfills and septic tanks; natural and man-made liners for sanitary landfills, waste stabilization ponds, and industrial liquid pits for ponds; and the conduct of various operational practices for sanitary landfills and septic tanks.

Article: Threlfall, D. and Dowiak, M. 1980. "Remedial Options for Ground Water Protection at Abandoned Solid Waste Disposal Facilities." EPA National Conference on Management of Uncontrolled Hazardous Waste Sites, Washington, D. C. Hazardous Materials Control Research Institute, Silver Springs, MD.

Subject: Groundwater control.

Description: ABSTRACT: Remedial options to minimize or prevent groundwater contamination and the importance of a site investigation prior to selection of remedial options are examined. A site investigation will determine subsurface conditions and characteristics of the disposed waste, and determine whether limited or extensive measures are required for groundwater protection.

A case history in which neutralized acid waste sludges were disposed in abandoned strip mines was examined. To reduce leachate production, a low permeability cover of bentonite soil additives, PVC membrances, or compaction of local soil was suggested or recommended.

Article: Ahnell, ... P., Jr., et al. 1980. "Environmental and Health Hazard Investigation of the Shenango Disposal Site." EPA National Conference on Management of Uncontrolled Hazardous Waste Sites, Washington, D. C. Hazardous Materials Control Research Institute, Silver Springs, MD.

Subject: Groundwater control.

Description: ABSTRACT: Recently, the Corps, in conjunction with the EPA, determined that hazardous wastes may be present at the Shenango disposal site. A study was done (1) to determine whether the wastes at the site jeopardize the health of the local

residents through contamination of air or ground water, (2) to identify the sources and kinds of wastes present at the site, and (3) to characterize the hydrogeologic conditions at the site and determine if contamination of ground or surface water has occurred. The approach of the study consisted of information retrieval, waste and hydrologic assessment, and site investigation.

Leachate Control

This usually involves the containment or collection of contaminated waters at disposal sites and may be accompanied by a treatment system. Leachate control and treatment research conducted for the Corps will be reported in a series of Engineering Technical Notes (ETN's) in the near future. Reviews of four reports and a manual are included.

Article: Geswein, A. J. 1975. "Liners for Land Disposal Sites -- An Assessment." U. S. Environmental Protection Agency, EPA/530/SW-137.

Subject: Leachate control.

Description: Using barriers to inhibit the movement of leachate into water sources is a relatively recent development in sanitary landfill design technology. The use of natural soils, asphalt treatments, polymeric membranes, and treated soils as liner materials is examined. Material properties, construction methods, costs, future materials, and leak detection are discussed. A construction specification for each liner material is included. All of the materials can be used successfully to contain fluids. Long-term effect of leachate on any liner material has not been determined.

Report: Schultz, D W. and Miklas, M. P. Jr. 1980. "Assessment of Liner Installation Procedures," U. S. EPA, Cincinnati, OH, Report No. EPA-600/9-80-010.

Subject: Disposal site liner emplacement technique.

Description: Southwest Research Institute is presently conducting a study to identify current methods and equipment used to (1) prepare supporting subgrade and (2) place liners at various impoundments in the United States. Subgrade preparation and liner placement activities have been observed at fifteen sites to date. The sites selected have included landfills, wastewater impoundments, and potable water reservoirs. Information obtained during each site visit included:

(1) Methods and equipment used to prepare the subgrade upon which the liner is to placed

(2) Methods and equipment used to place the liner material

(3) Special problems encountered and their solutions

(4) Important characteristics which must be considered during design and construction of an impoundment facility

Various aspects of subgrade preparation and liner placement are discussed herein. Photographs depicting construction and placement activities are presented.

Report: Fry, Z. B., and Styron, C. R., III. 1978. "The Use of Liner Materials for Selected FGD Waste Ponds." EPA-600/9-78-016, U. S. EPA, Cincinnati, OH.

Subject: Leachate control.

Description: A comparison was made of the compatibility of 18 liner materials and two selected FGD waste sludges. A total of 72 special test cells were constructed to contain the liners and the sludges. Devices were installed to collect leachate from the sludge, and the cells were pressurized to simulate a 30-ft* head of sludge. Physical and chemical tests were conducted prior to initiating the investigation, at the midpoint (12 months), and then scheduled for the end (24 months). The leachate collected for the 12 months has been analyzed for content of approximately 20 heavy metals. Also, observations and physical tests were made of the liner materials. At the midpoint of the investigation, two of the admix liner materials had disintegrated due to reaction with the FGD sludge. The leachate analysis from the majority of the other test cells indicated a considerable attenuation of the concentration of heavy metal content as compared with the analysis of the original or raw sludge. Further tests are scheduled during the remainder of the investigation to determine the cause of this phenomenon.

Report: Gunkel, R. C. 1980. "Membrane Liner Systems for Hazardous Waste Landfills." U. S. EPA Municipal Environmental Research Laboratory, Cincinnati, OH.

Subject: Leachate control.

Description: The Waterways Experiment Station is conducting a research program for the U. S. Environmental Protection Agency,

---

* A table of factors for converting U. S. customary units of measurement to metric (SI) is presented on page iv.

Cincinnati, Ohio, to evaluate several types of flexible membranes for use in hazardous waste landfills.

A test section has been constructed and is divided into twelve test items. These test items contain selected soil and aggregate materials that may be found at landfill sites within the United States. The flexible membrane is placed on selected materials, covered with a layer of sand, and subjected to traffic using three types of loading (tire, track, and cleated) that are used in landfill construction. The performance of the flexible membranes will be evaluated as to resistance to puncture and other defects.

<u>Manual</u>: Tolman, A. L., et al. 1978. "Guidance Manual for Minimizing Pollution from Waste Disposal Sites." U. S. Environmental Protection Agency, EPA/600/2-78-142.

<u>Subject</u>: Leachate control.

<u>Description</u>: Tolman et al. prepared a manual providing guidance in the selection of available engineering technology to reduce or eliminate leachate generation at existing dumps and landfills. The manual emphasized remedial measures for use during or after closure of landfills and dumps which do not meet current environmental standards.

<u>Gas Migration</u>

Gases and volatile compounds must be controlled at many hazardous waste sites both to allow access to the area and to prevent wider dispersion of contaminants. Gas and vapor movement is usually controlled by:

<u>a</u>. Cover construction.

<u>b</u>. Vertical barriers.

<u>c</u>. Control trench vents.

<u>d</u>. Pipe vents.

<u>e</u>. Vacuum collection of gas or vapor.

<u>f</u>. Liners/membranes.

Abstracts of a report and two articles are furnished.

<u>Report</u>: Genetelli, E. J., et al. 1976. "Gas and Leachate from Landfills: Formation, Collection, and Treatment." U. S. EPA Solid and Hazardous Waste Research Division, Cincinnati, OH. EPA-600/9-76-004.

Subject: Gas migration.

Description: A research symposium on sanitary landfills was held to bring together researchers, administrators, and other personnel to exchange state-of-the-art ideas and findings. This mechanism was utilized so that maximum coverage could be gained. Topic areas discussed were gas and leachate, their formation, collection, and treatment. The papers contained in this symposium represent the Solid and Hazardous Waste Research Division, Municipal Environmental Research Laboratory research on sanitary landfills.

Article: Stone, R. 1978. "Reclamation of Landfill Methane and Control of Off-Site Migration Hazards." Solid Wastes Management, Vol 21, No. 7, ASCE, New York, NY.

Subject: Gas migration.

Description: Methods of reclaiming and recycling the methane gas produced in landfills and in nature (i.e., in tar pits, peat bogs, and coal or oil deposits) by the biochemical decomposition of organics by methane bacteria are described. Two basic approaches to controlling the migration of methane gas from a completed sanitary landfill are impermeable barriers and ventilation systems. Gravel-filled trenches or wells on or near the sanitary landfill perimeter form a natural ventilation system to intercept laterally migrating gas. To be effective, however, impermeable barriers and permeable ventilation systems must be carefully designed and constructed, closely monitored, and conscientiously maintained.

Article: Stone, R. 1978. "Preventing the Underground Movement of Methane from Sanitary Landfills." Civil Engineering, Vol 48, No. 1, ASCE, New York, NY.

Subject: Gas migration.

Description: Alternatives for controlling methane gas migration from sanitary landfills are evaluated. The conditions leading to explosions and fires from concentrations of methane are discussed. Advantages and disadvantages of impermeable barriers, forced ventilation systems and natural ventilation systems are given. Alternative control systems are evaluated for effectiveness (the main consideration), maintainability and controllability. A forced induction system is considered safest, with trench/membrane barrier systems effective for controlling small amounts of methane. Other alternatives may not provide all the needed protection and safety. Trench/membrane systems are the easiest to maintain. Forced ventilation systems are the easiest to control.

Windblown Particulate Control

Wind erosion of contaminated soils is another pathway for waste movement from the site. Techniques for limiting wind erosion are generally similar to those employed in dust control and include the use of:

a. Physical stabilization.

b. Chemical stabilization.

c. Vegetative stabilization.

Descriptions of two reports and one article on this subject are included.

Report: Smith, T., et al. 1971. "Control of Wind Erosion," State of California, Dept. of Public Works, Division of Highways, Dec.

Subject: Control of wind erosion by sprayed-on chemicals.

Description: Sixteen different "spray on" materials for controlling erosion were obtained from various vendors and applied, following the vendors' directions, on the slope of a highway fill near Indio. The materials are described. The dilution rate, the application rate and the cost per acre are summarized. Each material was evaluated after a 6-month test period and classified as satisfactory, unsatisfactory, or marginal on the basis of visual examination. The maximum recorded wind velocity for each day of the test period is summarized. Pictures illustrating results are included. Observation of the performance of these materials will be continued for at least one more year.

Sixteen commercial products were tested.

Report: Mearns, R., et al. 1974. "Control of Wind Erosion with Spray-On Chemicals," Highway Research Report, CA-DOT-TL-2127-1-74-12, State of California Transportation Laboratory, Feb.

Subject: Control of wind erosion.

Description: The objective of this project was to evaluate the effectiveness of six spray-on erosion control chemicals in preventing wind erosion. The chemicals were applied to adjacent plots in an erosive area. The performance of the various chemicals was visually evaluated. The results indicated a need for further study. Fiber or straw used in conjunction with the chemicals was found to be of significant benefit. The numbers of products and the application rates were limited. All treatments were of some value, but only one was superior. The best treatment was Surfaseal at 198 gallons per acre over punched-in straw.

Article: Chepil, W. S., et al. 1963. "Vegetative and Nonvegetative Materials to Control Wind and Water Erosion," Soil Science of America Proceedings, Vol. 27, No. 1, Jan-Feb, p. 86-89.

Subject: Control of water/wind erosion with emulsions.

Description: ABSTRACT: Fine, medium, and coarse gravel spread uniformly at rates of 20, 50, and 100 tons per acre, respectively, adequately controlled wind erosion of smooth, bare, sandy loam where no traffic was involved.

Resin emulsion sprayed at 600 gallons of concentrate per acre and asphalt emulsion and cutback asphalt sprayed at 1,200 gallons of concentrate per acre adequately controlled wind erosion on level Sarpy sandy loam at estimated respective costs of $213, $247, and $335 per acre on a carload basis, in drums, at Manhattan, Kansas. Under similar conditions, 4,000 pounds of wheat straw mulch per acre anchored with a rolling disk packer was equally effective at an estimated cost of $89 per acre.

Quantities of latex emulsion sprayed at rates up to 225 gallons of concentrate per acre were not sufficient to control wind or water erosion on level or sloping ground. Starch treatments were also ineffective in controlling wind erosion under the conditions of the experiment.

On a 3:1 construction slope, at least 1,200 gallons of asphalt emulsion per acre sprayed uniformly on the surface was needed to control rill erosion. The treatment cost $335 per acre. In previous experiments on a 3:1 construction slope, prairie hay mulch at 4,000 pounds per acre uniformly spread and anchored with 400 gallons of asphalt emulsion per acre was equally effective at a cost of about $200 per acre.

Other References

The material reviewed and judged to be of some interest is grouped into sets for the convenience of the reader. The reader should recognize that many of the entries in the first set also apply to the others but are not repeated there. The sets are:

a. Surface water control.

b. Groundwater control.

c. Leachate control.

d. Gas migration.

e. Windblown particle control.

Surface water control

Neely, N., et al. 1981. "Remedial Actions at Hazardous Waste Sites," EPA 430/9-81-05, SW-910. U. S. Environmental Protection Agency, Cincinnati, OH. 230 pp.

Tolman, A. L., et al. 1978. "Guidance Manual for Minimizing Pollution from Waste Disposal Sites," EPA-600/2-78-142, U. S. Environmental Protection Agency, Cincinnati, OH.

EPA. 1982. "Remedial Action at Waste Disposal Sites," EPA-625/6-82-006, U. S. Environmental Protection Agency, Cincinnati, OH.

U. S. Soil Conservation Service. 1973. "Drainage of Agricultural Land" (Handbook), Water Information Center, Inc. Port Washington, NY.

Sally, H. L. 1965. Lining of Earthen Irrigation Channels. Asia Publishing Co. New York, NY. 119 pp.

Hassett, William H., and E. T. Conrad. 1981. "Remedial Actions for Open Dumps," Jour. of Env. Eng. Div. ASCE. 107(EEG):13171325.

U. S. Army Corps of Engineers. 1977. "Storage Treatment, Overflow, and Runoff Model-STORM," Hydrologic Engineering Center, Davis, CA.

Knisel, W. J., Jr. (ed.) 1980. "CREAMS, A Field Scale Model for Chemical Runoff and Erosion from Agricultural Management Systems," Vol I, II, and III. USDA-SEA, AR, Cons. Res. Rept, 24.

Geraghty and Miller. 1978. "Surface Impoundments and Their Effects on Groundwater Quality in the United States - A Preliminary Survey," EPA 570/978004. U. S. Environmental Protection Agency, Washington, DC, 1978.

Sowers, G. B., and G. F. Sowers. 1957. Soil Mechanics and Foundations 3rd ed. McMillian and Co., New York, NY.

Brunner, D. R., and Keller, D. J. 1971. "Sanitary Landfill Design and Operations," U. S. Environmental Protection Agency, Washington, DC, 149 pp.

Ferb, D. G. 1977. "Upgrading Hazardous Waste Disposal Sites" EPA/500/ SW-677. U. S. Environmental Protection Agency, Washington, DC.

Fields, T., Jr., and A. W. Lindsey. 1975. "Landfill Disposal of Hazardous Wastes: A Review of Literature and Known Approaches," EPA/530/SW-165. U. S. Environmental Protection Agency, Cincinnati, OH.

Emrich, G. H., and W. W. Beck, Jr. "Top Sealing to Minimize Leachate Generation -- Status Report," EPA-600/9-81-002b, U. S. Environmental Protection Agency, Cincinnati, OH. pp. 291-297.

Lutton, R. J., G. L. Regan, and L. W. Jones. 1979. "Design and Construction of Covers for Solid Waste Landfills." EPA-600/2-79-165. U. S. Environmental Protection Agency, Cincinnati, OH.

Geswein, A. J. 1975. "Liners for Land Disposal Sites," EPA/530/ SW-137 U. S. Environmental Protection Agency, Cincinnati, OH.

Spencer, W. F., and W. J. Farmer. 1980. "Assessment of the Vapor Behavior of Toxic Organic Chemicals." In Hague, R., 1980, Dynamics, Exposure and Hazard Assessment of Toxic Chemicals, Ann Arbor Science Publishers, Inc., Ann Arbor, MI. pp 143-161.

American Colloid Company. 1981. "Specification Volclay Bentonite SLS-70," Skokie, IL.

Pilie, R. J., et al. "Methods to Treat, Control, and Monitor Spilled Hazardous Materials," EPA-670/2-75-042, U. S. Environmental Protection Agency, Cincinnati, OH.

U. S. Army Corps of Engineers. 1959. Earth Embankments, EM 1110-2-2300.

Matrecon, Inc. 1980. "Lining of Waste Impoundment and Disposal Facilities," SW-870, U. S. Environmental Protection Agency Washington, DC.

Haxo, R. S., and R. M. White. 1977. "Liner Materials Exposed to Hazardous and Toxic Sludges," First Interim Report, EPA-600/2-77-081, U. S. Environmental Protection Agency, Cincinnati, OH.

Mallory, C. W., and M. A. Nawrocki. 1974. "Containment Area Facility Concepts for Dredged Material Separation, Drying, and Rehandling," CR D-74-6, U. S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Soil Conservation Service. 1975. Standards and Specifications for Soil Erosion and Sediment Control in Developing Areas, U. S. Department of Agriculture, College Park, MD.

West Virginia Department of Natural Resources, Division of Planning and Development and Division of Reclamation, in cooperation with Soil Conservation Service. 1975. Drainage Handbook for Surface Mining, U. S. Department of Agriculture, College Park, MD.

Maryland State Highway Administration. 1968. Specifications for Materials, Highways, Bridges, and Incidental Structures, Baltimore, MD.

American Association of State Highway and Transportation Officials. 1970. Standard Specifications for Highway Materials, Washington, DC.

Soil Conservation Service. 1969. Engineering Field Manual for Conservation Practices, U. S. Department of Agriculture, College Park, MD.

Soil Conservation Service. 1964. "Handbook of Channel Design for Soil and Water Conservation," Technical Paper No. 61, U. S. Department of Agriculture.

National Academy of Sciences, 1971. "Design of Culverts, Energy Dissipators and Filter Systems," Highway Research Record No. 373, Washington, DC.

Bohan, J. P. 1970. "Erosion and Riprap Requirements at Culvert and Storm-Drain Outlets," Research Report No. H-70-2, U. S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Fletcher, B. P., and J. L. Grace, Jr. 1972. "Practical Guidance for Estimating and Controlling Erosion at Culvert Outlets," Misc. Paper No. H-72-5, U. S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Highway Research Board. 1970. "Tentative Design Procedure for Riprap-Lined Channels," National Cooperative Highway Research Program Report No. 108, National Academy of Sciences.

Seelye, E. E. 1960. Data book for Civil Engineers Design, John Wiley & Sons, Inc., N.Y., NY.

Thronson, R. E. 1973. "Comparative Costs of Erosion and Sediment Control, Construction Activities," U. S. Environmental Protection Agency, EPA-430/9-73-016, Washington, DC.

Yarnell, D. L. 1935. "Rainfall Intensity -- Frequency Data," U. S. Department of Agriculture, Misc. Publication No. 204, Washington, DC.

Flevert, R. K., et al. 1955. Soil and Water Conservation Engineering, John Wiley & Sons, Inc., N.Y., NY.

Doyle, Timothy. "Surface Water Management at Hazardous Waste Sites." 1980. EPA National Conference on Management of Uncontrolled Hazardous Waste Sites, Washington, D. C. Hazardous Materials Control Research Institute, Silver Springs, MD.

Fry, Z. B., and C. R. Styron III. 1978. "The Use of Liner Materials for Selected FGD Waste Ponds," EPA Report No. 600/9-78-016, USEPA, Cincinnati, OH.

Lutton, R. J. 1978. "Selection of Cover for Solid Waste." NTIS EPA-600/7-78-016. USEPA, Cincinnati, OH.

Paige, Sidney, et al. 1980. "Preliminary Design and Cost Estimates for Remedial Actions at Hazardous Waste Disposal Sites," Hazardous Materials Control Research Inst., Silver Springs, MD.

Groundwater control

The Johnson Division. 1966. Ground Water and Wells, Universal Oil Products Co., Inc., St. Paul, Minnesota, 1966. pp. 286-94.

Harr, M. E. 1962. Groundwater and Seepage, McGraw-Hill Book Co., New York, 1962.

Amar, A. L. 1975. "Theory of Ground Water Recharge for a Strip Basin," Groundwater, 13(3):282-93.

Gregg, D. O. 1971. "Protective Pumping to Reduce Aquifer Pollution. Glynn County, Louisiana." Groundwater, 9(5).

Nobel, D. G. 1963. "Well Points for Dewatering," Groundwater, 1(3):21-36, 1963.

Shehan, N. T. 1977. "Injection/Extraction Well System — A Unique Seawater Intrusion Barrier," Groundwater, 15(1):32-51.

Leonards, G. A. (Editor) 1962. Foundation Engineering, McGraw-Hill Book Co., New York.

Office of Water Supply, Environmental Protection Agency. 1975. Manual of Water Well Construction Practices, EPA Report No. 570/9-75-001.

Clark, D. C. 1979. "Remedial Action Activities for Army Creek Landfill," EPA-600/9-79-0232. Municipal Solid Waste: Land Disposal. U. S. Environmental Protection Agency, Cincinnati, OH. pp 343-357.

Rishel, H. L., T. M. Boston, Schmidt, C. J. 1980. "Costs of Remedial Response Actions at Uncontrolled Hazardous Waste Sites," Draft Report. U. S. Environmental Protection Agency. Cincinnati, OH.

James, S. C. 1977. "The Indispensable (Sometimes Intractable) Landfill-Waste Disposal Engineering." Technology Review, Vol 79, U. S. EPA, Office of Solid Waste, Washington, D. C., RSIC A77-24959.

Huibregtse, K. R., and K. H. Kastman. 1981. "Development of a System to Protect Groundwater Threatened by Hazardous Spills on Land," EPA contract report 600/2-81-085, 143 p.

Josephson, J. 1981. "Hazardous Waste Landfills." Environmental Science and Technology, Vol 15, No. 3, American Chemical Society, Washington, D. C.

Kazmann, R. G., Kimbler, O. K., and Whitehead, W. R. 1974. "Management of Waste Fluids in Saline Aquifers," J. Irrigation and Drainage Div-ASCE, Vol 100, No. 4.

La Russo, R. S. 1963. "Wanapum Development — Slurry Trench and Grouted Cutoff," in Symposium on Grouts and Drilling Muds in Engineering Practice, British National Society of the Intern. Soc. of Soil Mech. and Foundation Engineering of the Inst. of Civil Engineers, May 1963, London.

Miller, S. P.. 1976. "Interim Containment System, Groundwater Treatment, Rocky Mountain Arsenal, Denver, Colorado," U. S. Army Engineer Waterways Experiment Station, Vicksburg, MS, 10 p. plus plates, figures.

Nelson, D. L., Cartwright, K., and Griffin, R. A. 1980. "A Landfill Design for a Sensitive Environment." Municipal and Industrial Waste Research and Practice, 3rd Conference, University of Wisconsin, Madison.

Aldrich, N. 1979. "Underground Injection Control Rules: Closing the Groundwater Protection Gap." Sludge, Vol 2, No. 3.

Bauner, A. R. 1980. "Handling of Waste Residuals from a Pesticide Manufacturing Facility." 53rd Annual Conference of the Water Pollution Control Federation, Las Vegas, NV. Water Pollution Control Federation, Washington, DC.

Braids, O. C., et al. 1977. "Effects of Industrial Hazardous Waste Disposal on the Ground Water Resource." In "Drinking Water Quality Enhancement Through Source Protection," R. B. Pojasek (Ed.), Ann Arbor Sci. Publ., Inc., Ann Arbor, Mich.

Breeden, C. M. 1980. "Measuring the Risks and Costs of Waste Disposal by Deep-Well Injection," Virginia Water Resources Research Center, Report 122.

Brunner, D. R., and Carnes, R. A. 1977. "Characteristics of Percolate of Solids and Hazardous Waste Deposits." Jour. Amer. Water Works Assn.

Cheremisinoff, N., et al. 1980. "Industrial and Hazardous Wastes Impoundment," Ann Arbor Science Publishers, Inc., Woburn, MA.

Dodds, R. B., Jurgens, E., and Freitag, C. A. 1978. "Retention of Radioactive Wastes at an Operating Uranium Mill Site," Organization for Economic Cooperation and Development Stabilization and Environmental Impact of Uranium Mill Tailings Conference, Albuquerque, NM.

U. S. Steel. U. S. Steel Sheet Piling: Design Extracts from Former Catalogs. Adv.-18605-52, Reprinted from Carnegie Steel Sheet Piling, Pittsburgh, PA.

Bethlehem Steel Co. 1971. Bethlehem Steel Sheet Piling: Manufacturer's Catalogs. SPECDATA, Folders 2790, 2570, Bethlehem, PA.

Bethlehem Steel Co. 1970. Steel Sheet Piling. Catalog 2620, Bethlehem, PA.

U. S. Steel. 1963. Hot Rolled Steel Shapes and Plates.

Bethlehem Steel Co. Bethlehem Structural Shapes, Catalog S-58-A, Bethlehem, PA.

Stubbs, F. W., Jr., Ed. 1959. <u>Handbook of Heavy Construction,</u> McGraw-Hill Book Co., New York.

Armco Drainage & Metal Products, Inc. 1958. <u>Handbook of Drainage and Construction Products,</u> The Lakeside Press, Chicago, IL.

Lane, K. S., and P. E. Wohlt. 1961. "Performance of Sheet Piling and Blankets for Sealing Missouri River Reservoirs," Report 65, 7th Congress on Large Dams, Rome.

Jacques, W. B. 1981. "Stopping Water with Chemical Grout" Civil Engineering - ASCE Vol. 51, No. 12 pp. 5962.

Office, Chief of Engineers. 1966. <u>Foundation Grouting: Planning</u>, EM 1110-2-3501.

Office, Chief of Engineers. 1963. <u>Foundation Grouting: Field Technique and Inspection</u>, EM 1110-2-3503.

Department of the Army. 1970. <u>Grouting Methods and Equipment</u>, TM 5-818-6, February 1970.

Office, Chief of Engineers. 1973. <u>Chemical Grouting</u>, EM 1110-2-3504.

Heandon, J., and T. Lenaham. 1976. "Grouting in Soils, Vol. 1, A State-of-the-Art Report," Federal Highway Admin., Report No. FHWA-RD-76-26, Washington, DC.

Dempsey, J. A., and Moller, K. 1970. <u>Grouting in Ground Engineering</u>, Institute of Civil Engineers, London.

Houlsby, A. C. 1977. "Engineering of Grout Curtains to Standards," Journal of the Geotechnical Engineering Division of ASCE, September.

American Cyanamid Company. 1975. All About Cyanamid AM-9 Chemical Grout, Wayne, NJ, 95 pp.

Karol, R. H. 1968. Chemical Grouting Technology," J. Soil Mech. Found. Div., ASCE, Vol. 94, No. SM1, Proc. Paper 5748, pp. 175-204.

Halliburton Services. 1976. Grouting in Soils, Vol 2. Design and Operations Manual, U. S. Department of Commerce, PB-259044, NTIS, Springfield, VA.

Revised Bibliography on Chemical Grouting. 1966. "Third Progress Report of the Committee on Grouting," W. K. Seaman, Chmn. J. Soil Mech. Found. Div., ASCE, Vol. 92, No. SM6, Proc. Paper 4469, November 1966. pp. 39-66.

Raymond International, Inc. 1967. Siroc Grout Technical Manual. New York.

Leachate control

Roe, H. B., and Q. C. Ayres. 1954. Engineering for Agricultural Drainage, McGraw-Hill Book Co., New York.

Department of the Army. 1966. Subsurface Drainage Facilities, Emergency Construction, TM 5-886-3.

K. W. Brown and Associates, Inc. 1980. "The Design and Management of Hazardous Waste Land Treatment Facilities (DMHLTF)," U. S. Environmental Protection Agency, Cincinnati, OH. Draft Report.

Overcash, M. R., and D. Pal. 1979. Design of Land Treatment Systems for Industrial Waste - Theory and Practices. Ann Arbor Science Pub. Inc. Ann Arbor, MI.

Neely, N. et al. 1981. "Remedial Actions at Hazardous Waste Site, Survey and Case Studies," EPA 430/9-81-05 U. S. Environmental Protection Agency. Cincinnati, OH.

Rishel, H. L., T. M. Boston, and C. J. Schmidt. 1981. "Costs of Remedial Response Actions at Uncontrolled Hazardous Waste Sites." Draft Report. U. S. Environmental Protection Agency, Cincinnati, OH.

Anderson, D., and Brown, K. W. 1981. "Organic Leachate Effects on the Permeability of Clay Liners," Proceedings of EPA 7th Annual Research Symposium, Vol 2.

Ali, E., and Moore, C. 1981. "Improved Techniques for Flow of Liquids Through Hazardous Waste Landfills," 7th Annual Research Symposium on Land Disposal of Municipal Solid and Hazardous Waste and

Resource Recovery, U. S. EPA Municipal Environmental Research Laboratory, Office of Research and Development, Cincinnati, OH.

Bernard, H. 1980. "Love Canal -- 2030 A.D." EPA National Conference on Management of Uncontrolled Hazardous Waste Sites. Hazardous Materials Control Research Institute, Silver Springs, MD.

Farmer, W. J., Yang, M., and Letey, J. 1980. "Land Disposal of Hexachlorobenzene Wastes," U. S. EPA Municipal Environmental Research Lab, Solid and Hazardous Waste Research Div., Cincinnati, OH. EPA-600/2-80-119.

Fuller, W. H., Amoozegar-Fard, A., Nieble, E., and Boyle, M. 1981. "Behavior of Cd, Ni and Zn in Single and Mixed Combinations in Landfill Leachates," 7th Annual Research Symposium on Land Disposal of Municipal Solid and Hazardous Waste and Resource Recovery, Philadelphia, PA. U. S. EPA Municipal Environmental Research Laboratory, Office of Research and Development, Cincinnati, OH.

Stephen, H., and T. Stephen. 1963. Solubilities of Inorganic and Organic Compounds, Macmillan, New York, Vol. 1, Part 1.

Fuller, W. W. 1980. "Soil Modification to Minimize Movement of Pollutants from Solid Waste Operations." Critical Reviews in Environmental Control, Vol 9, No. 3.

Garrett, B. C., McKown, M. M., Miller, M. P., Riggin, R. M. and Warner, J. S. 1981. "Development of a Solid Waste Leaching Procedure and Manual," 7th Annual Research Symposium on Land Disposal of Municipal Solid and Hazardous Waste and Resource Recovery, Philadelphia, PA. U. S. EPA Municipal Environmental Research Laboratory, Office of Research and Development, Cincinnati, OH.

Griffin, R. A., and Chow, S. J. 1980. "Disposal and Removal of Halogenated Hydrocarbons in Soils," U. S. EPA Municipal Environmental Research Laboratory, Cincinnati, OH. EPA-600/9-80-010.

Hemsley, W. and Koster, W. 1980. "Remedial Technique of Controlling and Treating Low Volume Leachate Discharge," EPA National Conference on Management of Uncontrolled Hazardous Wastes Sites, Washington, D. C. Hazardous Materials Control Research Institute, Silver Springs, MD.

Meiser, E. W., Earl, T. A., and Bodner, R. M. 1980. "Leachate Collection Using the Ground-Water Flow System: A Landfill Case History in Central Pennsylvania," University of Wisconsin Municipal and Industrial Waste Research and Practice 3rd Conference, Madison.

Lu, J., Morrison, R., and Stearns, R. 1981. "Leachate Production and Management from Municipal Landfills: Summary and Assessment,"

7th Annual Research Symposium on Land Disposal of Municipal Solid and Hazardous Waste and Resource Recovery. U. S. EPA Municipal Environmental Research Laboratory, Office of Research and Development, Cincinnati, OH.

Reindl, J. 1977. "Evaluating Design Alternatives for Landfill Construction," Communications Channels, Inc., Atlanta, GA.

Reindl, J. 1977. "Gathering Data: Most Important Step in Designing Landfill," Solid Waste Management, Vol 20, No. 9, Communication Channels, Inc., New York, NY.

Gas migration

Bowerman, F. R., et al. 1977. "A Case Study of the Los Angeles County Palos Verdes Landfill Gas Development Project," U. S. EPA Municipal Environmental Research Laboratory, Office of Research and Development, Cincinnati, OH. EPA-600/3-77-047.

EMCON Associates. 1980. "Methane Generation and Recovery from Landfills," Ann Arbor Science Publishers, Inc., Woburn, MA.

James, S. 1981. "Advances in the Recovery and Utilization of Landfill Gas," 7th Annual Research Symposium on Land Disposal of Municipal Solid and Hazardous Waste and Resource Recovery. U. S. EPA Municipal Environmental Research Laboratory, Office of Research and Development, Cincinnati, OH.

Hekimian, K. K., et al. 1976. "Methane Gas Recovery from Sanitary Landfills in Southern California," Energy: Tackling the Crisis, Proceedings of the Second Greater Los Angeles Area Energy Symposium, Western Periodicals Company, North Hollywood, CA.

McOmber, R., and C. Moore. 1981. "Field Verification of Landfill Methane Movement and Methane Control Systems," pp 104-115. EPA-600/9-81-002a. U. S. Environmental Protection Agency, Cincinnati, OH.

Moore, C. A. 1979. "Landfill Gas Generation, Migration and Controls." CRC Critical Rev. in Env. Control, Vol 9, No. 2, pp. 157-184.

Mohsen, M. F. M., Farquhar, G. J., and Kouwen, N. 1980. "Gas Migration and Vent Design at Landfill Sites," Water, Air, and Soil Pollution, Vol 13, No. 1.

Pacey, J. G. 1981. "Controlling Landfill Gas," Waste Age, Vol 12, No. 3.

Reindl, J. 1977. "Managing Gas and Leachate Production of Landfills," Solid Wastes Management, Vol 20, No. 7, Communication Channels, Inc., New York, NY.

Hague, R. 1980. Dynamics Exposure and Hazard Assessment of Toxic Chemicals. Ann Arbor Science Publishers, Inc. Ann Arbor, MI.

Farmer, W. J., et al. 1978. "Land Disposal of Hexachlorobenzene Wastes: Controlling Vapor Movements in Soils," EPA-600/9-78-016. U. S. Environmental Protection Agency, Cincinnati, OH.

Quinlivven, S., M. Ghassemi, and M. Senty. 1976. "Survey of Methods Used to Control Wastes Containing Hexachlorobenzene," EPA/530-SW-120C, U. S. Environmental Protection Agency, Washington, DC.

Suffet, I. H. 1977. Fate of Pollutants in the Air and Water Environments. John Wiley and Sons, New York.

Acurex Inc. "Guidance Manual for Closure of Hazardous Waste Surface Impoundments," U. S. Environmental Protection Agency, Cincinnati, OH, Draft Report (80-59 EE).

Matheson Co., Inc. 1966. Matheson Gas Data Book, 4th edition, Matheson Gas Products, East Rutherford, NJ.

Reid, R. C., and T. K. Sherwood. 1966. The Properties of Gases and Liquids, 2nd edition, McGraw-Hill, New York.

Rossini, F. D., et al. 1953. Selected Values of Physical and Thermodynamic Properties of Hydrocarbons and Related Compounds,, American Petroleum Institute Project 44, American Petroleum Institute, Pittsburgh, PA.

Tsederberg, N. V. 1965. Thermal Conductivity of Gases and Liquids, MIT Press, Cambridge, MA.

Windblown particulate control

Wyant, D. C., W. C. Sherwood, and H. N. Walker. 1972. "Erosion Prevention During Highway Construction by the Use of Sprayed-On Chemicals," Virginia Highway Research Council, Report VHRC-77-R1.

U. S. EPA. 1976. "Erosion and Sediment Control, Surface Mining in the Eastern U. S. Vol 1-2. EPA-625/3-76-006. U. S. Environmental Protection Agency, Cincinnati, OH.

Flower, F. B., et al. 1978. "A Study of Vegetation Problems Associated with Refuse Landfills," EPA-600/2-78-094. U. S. Environmental Protection Agency, Cincinnati, OH.

Dean, K. C., Havens, R., and Glantz, M. W. 1974. "Methods and Cost for Stabilizing Fine-Sized Mineral Wastes," U. S. Bureau of Mines, Report of Investigation 7876, Washington, DC.

Smith, T., et al. 1971. "Control of Wind Erosion," State of California, Dept. of Public Works, Division of Highways.

Mearns, R. et al. 1974. "Control of Wind Erosion with Sprayed-On Chemicals," Highway Research Report, CA-DOT-TL-2127-1-74-12, State of California Transportation Laboratory.

Chepil, W. S., et al. 1963. "Vegetative and Nonvegetative Materials to Control Wind and Water Erosion," Soil Science of America Proceedings, Vol. 27, No. 1, Jan.-Feb., p. 86-89.

PART VI: TREATMENT SYSTEMS

Introduction

The selection of treatment systems for toxic and hazardous wastes is difficult. The selection process is plagued by a rapidly changing technology brought about by a better understanding of these wastes and their response to treatment, a continuing increase in the number of pollutants to be removed and/or monitored, and a changing of the acceptable concentrations of such pollutants in the environment. In some instances, the acceptable percent removal of pollutants and the available funds may be the main factors controlling remedial system selection.

For the purposes of organization, the treatment processes discussed in this Part are divided into four general categories (i.e., physical, thermal, chemical, and biological) and those processes which span several categories are referenced for only one; e.g., land treatment and oxidation ponds.

Of the reference material available, the small percentage that appeared most applicable to the problems one might expect to encounter in cleanup of uncontrolled hazardous waste sites was selected for technical review and inclusion in Part VI as document reviews or references. The document reviews and references may not contain an answer to every technical question but should lead to other information that will--if indeed an answer exists.

CAPDET

The Computer Assisted Procedure for Design and Evaluation of Wastewater Treatment Systems (CAPDET) was originally developed by WES as an analytical tool to assist in the cost evaluation of wastewater treatment strategies proposed during the planning process conducted in accordance with the Urban Studies Program. It is the most comprehensive process design and cost estimating tool for domestic wastewater management.

Recently, CAPDET has been upgraded, revised, and applied on a program-wide basis for the preparation of cost estimates for EPA's Section 201 wastewater management plans. EPA's encouragement, followed by CAPDET's widespread use, has led to its adoption by the engineering profession as a proven technique for municipal wastewater treatment plant cost estimation and as an education tool in universities.

Because CAPDET was developed for use in evaluating municipal wastewater treatment requirements, no provisions exist for evaluating industrial or military/industrial complex treatment systems. It is estimated that 20 or more industrial waste treatment processes will be required to enhance the CAPDET program for hazardous and solid waste treatment applications; however, much of the existing CAPDET can be used with only slight modification. CAPDET uses a novel costing procedure which provides for estimation of quantities of materials and unit pricing to arrive at a cost for each treatment process. Not all of the processes modeled in CAPDET use this technique, however, because data were not available; therefore some will require updating to the unit pricing procedure.

In August of 1981, the U. S. Army Toxic and Hazardous Materials Agency requested that WES modify CAPDET for use in its Installation Restoration Program. The program's principal thrust is the cleanup of controlled and uncontrolled hazardous waste disposal sites at military installations under Army responsibility.

Report: Harris, R. W., Cullinane, M. J., Jr., and Sun, Paul T., ed. 1981. Process Design and Cost Estimating Algorithms for the Computer Assisted Procedure for Design and Evaluation of Wastewater Treatment Systems. U. S. EPA, Office of Water Program Operations Facilities Requirements Division, Priorities and Needs Assessment Branch and Office, Chief of Engineering, U. S. Army, Washington, DC.

Subject: Waste treatment (design and cost).

Description: This manual is provided to give persons concerned with planning, design and cost estimating associated with wastewater treatment facilities quick access to data for a number of wastewater treatment processes. The CAPDET model developed by the Corps of Engineers utilizes both parametric and unit cost estimating techniques. The approach is to prepare cost estimates for

users' input alternatives, ranking a number of treatment systems on the basis of cost effectiveness.

Section 1 of the manual provides general information related to planning and design of wastewater treatment facilities using the CAPDET model. Sections 2 and 3 contain design, quantities and cost equations for specific unit processes available within the CAPDET program.

Table 6-1. Process List

I. Metals Removal

- Neutralization
- Sedimentation*
- Precipitation
- Reduction

II. Particulate Removal

- Centrifugation*
- Flotation*
- Vacuum Filtration*
- Multi-Media Filtration*
- Package Pressure Filters*

III. Adsorption

- Carbon Fixed Bed*
- Carbon Pulse Bed
- Column Exchange

IV. Chemical Oxidation

- Ozone
- U-V Ozone

V. Membrane

- Reverse Osmosis
- Ultrafiltration

VI. Others

- Solidification/Stabilization
- Blending/Equalization
- Sludge Hauling and Landfilling*

VII. Thermal

- Rotary Kiln

* Processes presently modeled in CAPDET.

The Section 2 unit processes are suitable for flows within 0.3- to 300-mgd range and include: activated sludge, belt filter, blowers, carbon adsorption, centrifugation, chemical coagulation, chemical feed systems, chlorination, clarification, denitrification, digestion, equalization, filtration, filter press, flotation, incineration, ion exchange, lagoons, land treatment, 2-stage lime treatment, microscreening, nitrification, oxidation ditch, post aeration, preliminary treatment, pumping, pressure filtration, recarbonation, rotating biological contactor system, sludge drying beds, sludge hauling and landfilling, thickening, trickling filters, vacuum filtration, and wet oxidation.

Section 3 presents a library of processes developed for application to facilities with small flows; e.g., 0.01 to 0.5 mgd. Included are activated sludge, bar screens, chlorination, lagoons, lagoon upgrading, land treatment, oxidation ditch, pumping, septic tank and tile fields, and sludge drying beds.

Physical Treatment

The abstract and references include:

a. Coagulation and settling.

b. Filtering.

c. Mechanical dewatering.

d. Oil-water separation.

e. Flotation.

f. Extraction.

g. Evaporation.

h. Distillation.

i. Land application.

j. Membrane separation.

Coagulation and Settling

This process can be achieved in a number of ways, and there are numerous references. A review of the various techniques as well as their cost and effectiveness in handling industrial waste was prepared by Mace and Laks. A description of their article follows.

Article: Mace, G. R., and Laks, R. 1978. "Developments in Gravity Sedimentation," Chem. Eng. Prog., 74, 7, 77.

Subject: Clarification — Industrial Waste.

Description: Mace and Laks reviewed the operating parameters and economics of clarifiers, solids contact clarifiers, lamella separators, and inclined tube settlers. Two industrial wastewaters were used as examples for economic comparisons.

Filtering

The effectiveness of the various filtration processes in treatment of toxic and hazardous wastes probably has not been examined for many of the wastes that might be encountered. The review which follows describes an update summary of ongoing research.

Article: Lyman, W. J. 1980. "Inorganic Hazardous Waste Treatment." In Shultz, D. and Black, D. Treatment of Hazardous Waste: Proceeding of the Sixth Annual Research Symposium, EPA-600/9-80-011. U. S. Environmental Protection Agency, Washington, DC. p. 62.

Subject: Filtering.

Description: This report describes an ongoing program being conducted for EPA's Solid and Hazardous Wastes Division of MERL, Cincinnati, Ohio. The objective of the program is to identify, develop, and demonstrate selected treatment techniques for hazardous wastes in the municipal sector. To some extent the program is focused on wastes containing heavy metals and, to a lesser extent, on wastes containing organic as well as inorganic components. Current plans include demonstration tests for three treatment techniques: (1) a solvent extraction process for the treatment of sludges containing both inorganic and organic components; (2) a magnetic separation process for the treatment of sludges containing ferromagnetic or paramagnetic solids; and (3) a novel precipitation-filtration-adsorption process for treating acidic mixed plating wastes (of very high ionic strength) for both heavy metal and organics removal.

Mechanical dewatering

The amount of literature on this process that appears to be related to remedial techniques is limited. Two reviews are included: one of these deals with cost estimation and the other with system selection.

Article: Okey, R. W. et al. 1979. "Waste-Sludge Treatment in the CPI," Chemical Engineering, Vol 86, No. 3, 29 January 1979, pp. 86-100.

Subject: Mechanical dewatering.

Description: Examines thickening and dewatering equipment, presenting design and operational parameters, and plant and laboratory performance data. Covers pretreatment, sedimentation,

flotation, centrifugation, vacuum-drum filtration, precoat filtration, horizontal belt filtration, belt-press filtration, pressure filtration, reverse osmosis, ultrafiltration, secondary sludge treatment, chemical fixation, and byproduct recovery. Tables and illustrations.

Report: Center Corp. 1979. "Sludge Disposal Cost Minimization," USEPA, Cincinnati, OH, 161 pp.

Subject: Mechanical dewatering.

Description: This manual is a guide for the selection of dewatering systems for inorganic sludge. Topics discussed include the economics of sludge disposal; concentration of industrial inorganic sludge; design considerations; equipment operation; and handling sludge in the plant.

Oil-water separation

Three reviews of articles dealing with the separation of oil and grease from industrial wastewaters are included.

Article: Ford, D. L., and Elton, R. L. 1977. "Removal of Oil and Grease from Industrial Wastewater," Chem. Eng., 84, 22, 49.

Subject: Oil-water separation.

Description: Oil and grease removal from industrial wastewater was discussed by Ford and Elton. Some of the physicochemical processes that were potentially applicable were dissolved air flotation, coagulation-flocculation, filtration, coalescers, membrane processes, and activated carbon adsorption. Analytical techniques for measuring oil and grease were also presented.

Article: Kramer, G. R. et al. 1979. "Electrolytic Treatment of Oily Wastewater." Proc. 34th Ind. Waste Conf., Purdue Univ., Ext. Ser., 673.

Subject: Oil-water separation.

Description: Kramer et al. concluded that electrolytic treatment systems could be properly designed to remove economically up to 90 percent of the oils and greases from gravity separator effluent. Oil removal efficiency was dependent on flow rate, amperage to the electrodes, and concentration of oil and grease in the influent. Approximately 7.9 to 10.6 kWh/m^3 were required for 80 percent oil removal in wastes containing less than 100 mg/l oil, while for oil concentrations of 200 to 400 mg/l, 13.2 to

15.9 kWh/m^3 were needed to produce comparable oil removal efficiencies. Power efficiency was dependent on electrode surface condition and spacing.

Article: Kulowiec, J. J. 1979. "Techniques for Removing Oil and Grease from Industrial Wastewater." Poll. Eng. II, 2, 49.

Subject: Oil-water separation.

Description: An overview of techniques for removing oil and grease from industrial wastewater was presented by Kulowiec. Gravity separation, DAF, chemical treatment, membrane processes, biological treatment, and activated carbon adsorption were covered.

Flotation

The literature revealed no single document that dealt with the many aspects of flotation. However, numerous authors reported results on dissolved air flotation and foam separation (see the list of references following Part VI). Topics ranged from theory, removal of oil, foam fractionation of spent sulfite liquor, continuous foam fractionation of dilute kraft black liquor, colloid flotation, the effect of hot water on dissolved air flotation, the clarification of activated sludge effluent by dissolved air flotation, algae recovery by ozone-induced flotation, coagulation, ion-precipitation and electrolytic process. A series of 16 references are included.

Extraction

The absence of data in the literature suggests that the use of extraction methods for use on industrial wastewaters has not been studied to any significant extent. A report published by the EPA in 1975 describes some potential applications.

Report: Davidson, R. R. 1975. "Extraction or Destruction of Chemical Pollutants from Aqueous Waste Streams," US EPA-600/2-77/148, Ada, Okla. Jul 75.

Subject: Extraction.

Description: The use of solvent extraction and ozonation to treat various industrial wastewaters was studied. Most were light, chlorinated hydrocarbon, solvent wastes and were principally extracted with a high molecular weight paraffin petroleum fraction.

Distribution data on related pure chlorinated compounds were also obtained. The economics of solvent extraction versus steam stripping was examined. Though chlorinated solvents can be effectively removed by extraction, stripping appears to be more economical. A toluene diamine wastewater was found treatable with benzene. In all these wastes there are unextractable fractions. Attempts were made to treat glycol, toluene diamine and light chlorinated hydrocarbon wastewaters with ozone, but results were not satisfactory.

Evaporation

The evaporation process is frequently used for handling electroplating waste problems, but it also has been used in pesticide, pulp, and phosphate waste management as well as ethylene glycol and water reclamation. Evaporative lagoons which are used for a wide variety of toxic and hazardous wastes are discussed under the heading Lagoons in subsequent paragraphs. Thin film evaporation of toxic and hazardous wastes that might be applicable to remedial actions is included in process evaluation studies now being performed by WES for DARCOM. Preliminary results show a great deal of promise. A description of an article on pesticide waste is included. The other material reviewed is shown in the list of references.

Article: Hall, Charles V. 1980. "Holding and Evaporation of Pesticide Waste." Sixth Annual Research Symposium on Treatment and Disposal of Hazardous Wastes, U. S. EPA, Cincinnati, OH.

Subject: Evaporation-pesticide waste.

Description: Following seven years use of a 12-ft by 30-ft concrete pit filled with equal layers of gravel, soil, and gravel for disposal of over 40 different pesticide solutions, a three-year systematic evaluation was made of residues, bacterial activity, and contamination of the surrounding environment. Results show no significant accumulation of hazardous residues; biological degradation has and is still occurring, and almost normal biological activity is still in progress. There has been no leakage of chemicals and no pollution of the station well or other surrounding area. The system has been highly satisfactory.

Distillation

The distillation process, while useful in some industrial operations, may not be readily applicable to remedial response requirements. One article review on general design practices and two references on

specific applications related to pulp and paper products and to ethylbenzene manufacture are included.

Article: Fair, J. R. 1977. "Advances in Distillation System Design." Chem. Eng. Progr., 73, 11, 78.

Subject: Distillation system design.

Description: Fair reviewed the state of the art of distillation system design, presented a computer design program, and evaluated multiple-separation and single-separation systems.

Land treatment

The application of wastewater to the land is among the oldest of waste treatment processes. However, most of these systems were "rule of thumb" designs, and while many of these systems worked well the lessons learned were seldom in a form that could be used as design guidelines. Land treatment was the subject of intensive research in the 1970's as scientists and engineers made attempts to provide specific design guidelines for a wide range of environmental conditions that would maximize system efficiency and cost effectiveness.

The most well known design document summarizing this research and the experiences of the profession over the last few decades was produced jointly by the Corps and EPA and is described below.

Manual: U. S. EPA, U. S. Army Corps of Engineers, USDA. 1977, 1981. Process Design Manual for Land Treatment of Muncipal Wastewater, EPA 625/1-77008, Oct. 1977; and EPA 625/1-81-013, Oct. 1981. (COE EM 1110-1-501, 1981).

Subject: Land application -- design manual.

Description: Procedures for the design of land treatment systems are reviewed in this manual. Emphasis is given to slow rate, rapid infiltration, and overland flow processes. Basic unit operations and unit processes are discussed in detail, and design concepts and criteria for both large and small scale systems presented. The 1981 document is a revision of the 1977 manual and includes consideration of the large amount of research data and operating experience that has become available in recent years.

The passage of 1976 legislation dealing with toxic and hazardous wastes (the Resource Conservation and Recovery Act (RCRA) and the Toxic Substances Control Act (TSCA)) generated interest in using land

application techniques to treat some industrial wastes. Some of the results are promising, but some work resulted in the contamination of land areas. Some of these lands in turn required treatment (detoxification). Thus, it is apparent that land application is a viable option for some remedial response actions, but extreme care must be exercised. Reviews of two articles, one book, and a report dealing with toxic organic and inorganic wastes are included.

Article: Sadig, M., and Zaidi, T. H. 1981. "The Adsorption Characteristics of Soils and Removal of Cadmium and Nickel from Wastewaters," Water, Air, and Soil Poll., Vol 16. p. 293.

Subject: Land treatment.

Description: Abstract. The interactions between the adsorption characteristics of 27 experimental soils and the sorption of Cd and Ni from the municipal wastewaters were investigated in this study. The removal of these elements from soil solution was followed for 50 days.

All the adsorption characteristics, except cation exchange capacity and organic matter, were significantly correlated to the sorption of Cd after one day's shaking. After 7 days of shaking, none of the soil adsorption characteristics except free $CaCO_3$ was significantly correlated to Cd removal from wastewater. The soil-saturated paste pH and suspension pH were strongly correlated to Cd sorption throughout this experiment.

The behavior of Ni in soils was different from that of Cd. Surface area, total Fe, and total Al were significantly correlated to Ni sorption. The correlation between Ni removal and pH was stronger than any other parameter studied. After 7 day's shaking, clay content and total Ca were not significantly correlated to Ni sorption.

The cation exchange capacity of the soils was not significantly correlated to Cd or Ni sorption in this experiment. It seems that in the experimental soils, concentrations of Cd and Ni were probably not controlled by adsorption process. The precipitation process was probably playing a major role in the removal of these elements from the municipal wastewaters.

As observed in this experiment, the cation exchange capacity of experimental soils was a poor parameter to define sorption capacity of these soils for Cd and Ni. The guidelines for determining the soil sludge load, which are mainly based on the cation exchange capacity of soils, should be revised.

Article: Jenkins, T. 1980. "Toxic Volatile Organics Removal by Overland Flow Land Treatment," Proceedings of the 53rd Annual Conference of the Water Pollution Control Federation, 2626 Pennsylvania Avenue, N.W., Washington, DC.

Subject: Land application - toxic organics.

Description: The ability of overland flow systems to treat and remove toxic volatile organics from wastewater was studied at sites in Hanover, NH, and Utica, MS. The overall efficiency of removing added test substances was excellent, ranging from 80 to 100 percent depending on the specific volatile substance and the application rate used. The actual percent removal was found to be a function of detention time. The removal process was found to be well described by first order kinetics for all the volatile substances tested.

Biodegradation and sorption on suspended matter were eliminated as major removal processes. Rates of removal were consistent with a volatilization mechanism where the kinetics of removal were dependent mainly on the air/water partition coefficient (Henry's law of constants) of the test substances and the average water depth on the slope. Removal rates were not very temperature dependent.

Book: Overcash, M. R., and Pal, Dhiral. 1981. Decomposition of Toxic and Non-Toxic Organic Compounds in Soils, Ann Arbor Science. Woburn, MA. 375 pp.

Subject: Land treatment.

Description: This book offers information on the terrestrial effects of various toxic, hazardous and non-toxic organic compounds. Decomposition, leaching, adsorption, plant uptake, microbial response, critical toxic levels and pathways for chemical additions to the plant/soil system are discussed for various organics. Organic categories included are:

(1) Polychlorinated biphenyls (PCB)

(2) Aromatics

(3) Phenols/phenolics

(4) Surfactant/detergents

(5) Miscellaneous compounds

This information is critical for the development of design criteria for land treatment of industrial wastes.

Report: Davidson, J. M. et al. 1980. "Adsorption, Movement, and Biological Degradation of Large Concentrations of Selected Pesticides in Soils," U. S. EPA-600/280124, Cincinnati, OH.

Subject: Toxic organics in soil.

Description: Because of the importance of soil in biologically reducing the quantity and retarding the rate of pollutant movement into groundwater, this laboratory study was initiated to evaluate the adsorption, mobility, and degradation of large concentrations of the pesticides atrazine, methyl parathion, terbacil, trifluralin, and 2,4-D in soils representing four major soil orders in the United States.

Equilibrium adsorption isotherms of the nonlinear Freundlich type were obtained for all pesticides and the four soils. Pesticides solution concentrations used in the study ranged from zero to the aqueous solubility limit of each pesticide. The mobility of each pesticide increased as the concentration of the pesticide in the soil solution phase increased.

The observed increase in pesticide mobility for large pesticide concentrations in the soil invalidates, in many cases, the usefulness of the existing low concentration data base for designing pesticide waste disposal sites. Owing to the increased mobility and lower microbial decomposition rates of many pesticides when introduced into soils at waste disposal concentrations, the potential for groundwater contamination is increased significantly. The data presented in this report should be given consideration when designing waste disposal sites for pesticides. The low concentration data base for pesticide mobility may be reasonable when considering pesticides with low aqueous solubilities; however, this should not be accepted without verification.

Membrane separation

Ultrafiltration and reverse osmosis have been proven to be effective in treating a wide range of wastewater problems and, while expensive, usually offer a high percentage of removal for many pollutants.

These processes used singly or in combination have been applied for removal of:

a. Heavy metal ions.

b. Acids.

c. Bases.

d. Color.

e. Total dissolved solids.

f. Uranium yellowcake.

g. Phosphates.

h. Chlorinated organic.

i. Oil and latex.

j. Nitrates of toluene.

k. Surfactants.

l. Colloids.

Reviews of three of many available documents are furnished. These three are summaries of proven applications, and two of them contain cost data.

Article: Cruver, J. E. 1973. "Reverse Osmosis for WateReuse." In: Complete WateReuse -- Industry's Opportunity. American Institute of Chemical Engineers, New York, p. 619.

Subject: Membrane separation.

Description: Cruver summarized the status of development of reverse osmosis processing for reuse of acid mine drainage, municipal sewage effluents and some industrial streams. Current capital and operating costs were presented and future improvements outlined. Technical feasibility of spiral-wound RO processing for use of many industrial and municipal waste streams has been demonstrated. Limitations to the application of RO to water, wastewater, and other aqueous solutions were listed.

Article: Kellar, R. A. 1979. "Reverse Osmosis," Water and Sew. Works, 126, Ref. No. R-103.

Subject: Membrane separation.

Description: Kellar outlined a few applications of RO systems and summarized the theory and principles of RO in text and illustrated form. Cellulose acetate and aromatic polyamide commercial RO membranes, and design considerations were described.

Report: Spiewak, I. 1980. "Survey of Desalting Processes for Use in Wastewater Treatment," Publication ORNL-HUD.21UC-41-Health and Safety; Atomic Energy Commission, Oak Ridge National Laboratory. 31 pp.

Subject: Membrane separation.

Description: Spiewak conducted a review of the major aspects of desalting technology and reviewed the more promising methods. These included electrodialysis, reverse osmosis, dynamic membrane hyperfiltration, and distillation. Nearly all the processes lead to a product water of greater purity than that of most natural waters used for municipal supplies. However, these processes also produce a resultant concentrate which is very difficult to dispose

of. Cost estimates were formulated for various systems alternating between complete recycle and no recycle.

Book: DeRenzo, D. J., ed. 1978. Unit Operations for Treatment of Hazardous Industrial Wastes, Noyes Data Corp., Park Ridge, NJ.

Subject: Unit operations -- hazardous waste.

Description: This book examines over 40 physical or biological unit operations for their applicability to treating hazardous wastes. Included are process descriptions, applications to date, energy requirements, economic analyses and outlook for industrial waste treatment. Treatment processes include: carbon adsorption, resin adsorption, activated sludge, aerated lagoons, anaerobic digestion, composting, enzymes, trickling filters, waste stabilization ponds, calcination, catalysis, centrifugation, chlorinolysis, dialysis, dissolution, distillation, electrodialysis, electrolysis, electrophoresis, evaporation, filtration, precipitation, flocculation, sedimentation, flotation, freeze crystallization, freeze drying, suspension freezing, high-gradient magnetic separation, hydrolysis, ion exchange, liquid ion exchange, liquid-liquid extraction of organics, microwave discharge, neutralization, chemical oxidation, ozonation, photolysis, chemical reduction, reverse osmosis, steam distillation, air stripping, steam stripping, ultrafiltration, zone refining.

Chemical Treatment

Chemical treatment processes may become essential tools during the cleanup and maintenance of uncontrolled hazardous waste dump sites. There are an almost endless number of chemical and pseudo-chemical processes that could be considered. The ones addressed in this bibliography are:

a. Chemical fixation/stabilization/encapsulation.

b. Chemical coagulation.

c. Carbon adsorption.

d. Chemical reduction.

e. Ion exchange.

f. Neutralization.

g. Stripping.

h. Chemical oxidation.

Chemical fixation, solidification, stabilization, encapsulation

The terms used here have different meanings. Encapsulation, for example, runs the gamut from sealing drums and materials in polyethylene jackets, concrete vaults, or rings, to encapsulation by chemical addition (i.e., actually coating small grains of material). Reviews of a report and an article on encapsulation are included.

Report: Lubowitz, H. R., et al. 1977. "Development of a Polymeric Cementing and Encapsulating Process for Managing Hazardous Wastes," U. S. EPA, 600/2-77-045, Cincinnati, OH.

Subject: Encapsulation.

Description: This report provides method, materials, evaluations, and engineering for managing hazardous wastes employing an organic, polymeric cementing and encapsulating process (TRW process). Specimens of cubic dimensions three inches on edge, consisting of wastes cemented with 3 to 4 percent by weight of polybutadiene binder and encapsulated by 1/4-inch polyethylene jackets, were fabricated with selected wastes and subjected to exacting leaching conditions and mechanical testing. They were found to exhibit excellent retention of contaminants in leaching by a broad spectrum of aqueous solutions and to withstand degradation under high compressive and impact mechanical forces.

There is a spectrum of difficult-to-manage hazardous waste for which the TRW process of agglomeration and polymeric encapsulation appears to be uniquely applicable. For example, some wastes contain contaminating compounds in the form of alkali metal salts, e.g. sodium metaarsenate, that resist "fixation" by resins (inorganic as well as organic) and may be readily dispersed by dissolution from resin-localized waste (unencapsulated) into the ecology. Others contain nonsoluble compounds such as arsenic trisulfide which may be disseminated by physical dispersion. In addition, unencapsulated wastes localized satisfactorily by resins under certain conditions may retain resistance to delocalization encapsulation.

Article: Lobowitz, H. R., Telles, R. W., and Unger, S. L. 1980. "Encapsulation of 55-Gal Drums Holding Hazardous Wastes." In Shultz, D. and Black D., Treatment of Hazardous Waste: Proceedings of the Sixth Annual Research Symposium, EPA-600/9-80-011. U. S. Environmental Protection Agency, Washington, DC, p. 43.

Subject: Encapsulation/Admixing/Overpacking.

Description: Hazardous wastes that corrode 208 l (55-gal) metal drums present a serious potential threat to the well-being of man

and his environment. To render drums secure and safe for transporting to and final deposit in a landfill, investigations were carried out to overpack them with polyethylene (PE) encapsulates.

PE receivers, 6.35-mm- (1/4-in.-) thick wall and wide-mouth, and PE flat sheet, 6.35-mm (1/4-in.) thick, were employed for fabricating encapsulates. After insertion of corroding drums, the receivers were weld sealed. Encapsulates so fabricated were expected to exhibit satisfactory performance. (In contrast, containers sealed conventionally, rather than welded, by use of lids and threads, gaskets, sealants, and hoops, were not expected to give rise to safe transportability of wastes and long-term stability of contaminants under landfill conditions.) The encapsulates provided a unique service because wide-mouth PE containers were not commercially available for securing 208 l (55-gal) drums and/or complying with Department of Transportation specifications governing containers for use in transporting hazardous wastes.

A prototype apparatus was designed and constructed to fabricate PE encapsulates by welding. The apparatus was analogous to that employed in commercially built welding of the PE pipe.

Chemical stabilization/solidification or fixation is defined and described in the following report prepared by WES for EPA:

Report: U. S. Army Engineer Waterways Experiment Station. 1979. "Survey of Solidification/Stabilization Technology for Hazardous Industrial Wastes." U. S. EPA, NTIS PB-299-206, Springfield, VA.

Subject: Chemical fixation/stabilization.

Description: Stabilization/solidification or fixation is a process for treating industrial solid wastes (primarily sludges) that contain hazardous constituents to prevent dissolution and loss of toxic materials into the environment. Most of these treatment processes are designed to produce a monolithic solid of low permeability. Some of the stabilization/solidification processes can further control the loss of toxic materials by (a) reacting chemically with the toxic constituents to produce new inert solid compounds that bind the potential pollutants into stable crystal lattices; (b) controlling the pH and redox potential so that toxic compounds are maintained under conditions in which the materials have minimum solubility; (c) covering the solid waste material with a coating that does not react with the waste, but prevents water from reaching the material. Present solidification/stabilization systems are grouped into seven classes of processes. The advantages and disadvantages of each approach are discussed. Abstracts from technical information furnished by companies developing or marketing solidification/stabilization processes or marketing equipment specifically for these processes are presented.

The effectiveness of fixation and encapsulation and techniques for estimating pollution potential from certain "chemical fixed" wastes are addressed in a series of articles and reports prepared by WES for EPA. These cover leaching values and physical testing of sample, large-scale lysimeter operations and field evaluation at disposal sites. Those judged most applicable to remedial response problems are shown in the list of references.

Chemical coagulation/flocculation

The use of chemicals to separate inorganic as well as some organic substances from water, wastewaters, and other media has been extensive in agriculture and industry and by municipalities. In remedial action work, the application may involve the cleanup of soils and sediments where spills have occurred. Some of the work performed in association with the Corps' Dredged Material Research Program (DMRP) may contain information of value for these operations. A review of one DMRP document follows:

Report: Hill, Donald O. 1974. "An Assessment of Chemical Flocculants and Friction Reducing Agents for Application in Dredging and Dredged Material Disposal," DMRP Work Unit #6C04, U. S. Army Engineer Waterways Experiment Station, Office of Dredged Material Research, Vicksburg, MS.

Subject: Chemical coagulation/flocculation.

Description: This report presents results of an investigation into possible use of chemical flocculants and friction reducers for application to dredging and dredged materials disposal. Included are both theoretical considerations and applications. Concepts are developed for processing dredged material by coagulation and flocculation to effect separation of suspended solids from water and to effect turbidity control as well as friction reduction by chemical additives. There is an assessment of the feasibility of using chemical additives to increase flocculation and friction reduction and finally consideration of a variety of dredging and disposal environments (freshwater lakes, estuaries and open ocean) for use of flocculants and friction reducers.

This process is most often used by the metal finishing/plating industry, but it also is used by the textile industry, segments of the petroleum industry, and others. The list of references following Part VI shows some of these applications.

Carbon adsorption

The potential for use of the carbon adsorption process in conducting remedial responses is well recognized. Its use in the industries that generate many of the priority pollutants has caused an extensive amount of research to be conducted on this project. Reviews of a design manual, an article on the operation of a mobile carbon adsorption system designed for cleanup, and a progress report on a study designed to evaluate the effectiveness of granular activated carbon (GAC) in treating selected chemicals on the hazardous substances test are included; selected references showing the effectiveness and/or potential of this treatment process fo: a variety of pollutants are also included.

Manual: U. S. EPA. 1973. Process Design Manual for Carbon Adsorption. U. S. EPA Technology Transfer, 625/1-71-002a.

Subject: Carbon adsorption.

Description: This design manual provides the reader with information on activated carbon adsorption principles, pilot plant techniques, general and detailed process design considerations, cost, and operational requirements. Existing or planned facilities are also discussed.

Article: LaFornara, Joseph P. 1978. "Cleanup After Spill of Toxic Substances," WPCF J. Apr 78, V50, N4, P617 (11).

Subject: Toxic substance spills — carbon adsorption.

Description: Survey report: Six case histories employing EPA's hazardous materials spills treatment trailer are reviewed. The trailer's 200-gpm treatment system has three mixed-media filters and three activated carbon columns to remove suspended, precipitated, and organic soluble materials. Spills of PCB, pentachlorophenol, kepone, tremide (chlordane, heptachlor, aldrin, and dieldrin), toxaphene, and dinitro-butylphenol were treated by the EPA trailer, which was generally successful in mitigating environmental effects by filtering and carbon-adsorption. Ninety percent removal was achieved for 21 out of 23 compounds.

Project: Royer, M. D. Pilot Plant Operation and Data Acquisition and Analysis, Contract/Grant No. CA33-11805 1/78 to 12/83, U. S. Environmental Protection Agency, Office of Research and Development, Municipal Environmental Research Lab., Woodbridge Ave., Edison, NJ.

Subject: Carbon adsorption — hazardous substances.

Description: The purpose of this project is to evaluate, on a pilot scale, the use of GAC to remove organic contaminants from water.

As part of this study, chemicals on the EPA Hazardous Substances List (Federal Register 40 CFR 116) are subject to isotherm and column tests in order to expand the information base for rapidly formulating performance estimates of GAC treatment. The collection of isotherm and pilot-scale column data on three chemicals--phenol, m-cresol, and quinoline--on the EPA Hazardous Substances List has been completed. The accuracy of predictions derived from isotherm data has been examined by comparing predicted carbon usage rates with usage rates obtained in column tests. The predicted usage rates were moderately accurate (40 percent error). Pilot-scale tests have also been run to evaluate the feasibility of GAC treatment for several mixed wastes from uncontrolled industrial waste disposal sites.

Chlorination

The handbook, prepared by G. C. White, provides information on a wide range of application for chlorine.

Book: White, George C. 1972. Handbook of Chlorination, Van Nostrand Reinhold Co., New York.

Subject: Chlorination.

Description: This book provides pertinent information on chlorination as it is applied to potable water, wastewater, cooling water, industrial water and swimming pools. Chlorine dioxide and hypochlorination are also discussed.

More information on specific application is available in the references noted at the end of Part VI of this report.

Ion exchange

The ion exchange process is most frequently used in the metal processing and metal electroplating industries. Research conducted at the WES has shown that the ion exchange principle can be used in the clarification of waste stream generated during dredge material disposal operations. There may be a direct application of this technology to management of waste streams and/or ponded fluids encountered during remedial action activities. Reviews of a manual and a report on this subject are included.

Manual: Office, Chief of Engineers, Department of the Army. 1978. Treatment of Contaminated Dredged Material, Engineering Manual EM 1110-2-5021, Washington, D.C.

Subject: Treatment of contaminated dredged material slurries generated by hydraulic dredging operations.

Description: This manual synthesizes the results of several research studies and provides an overview of the problems associated with treating slurries generated by hydraulic dredging operations. Although the effluent from a properly designed and operated containment area will usually not require further treatment, in certain cases the levels of suspended solids and/or chemical constituents in the effluent water may be in excess of those levels specified by existing criteria. Since the levels of chemical constituents in the effluent water are related to its suspended solids content, the reduction of suspended solids results in reduced levels of chemical constituents. This may be accomplished by filtration or by coagulation method. Coagulant aids may be introduced into the dredge pipeline before disposal to enhance sedimentation or may be used to treat the containment area effluents to acceptable levels. Open-water disposal of contaminated dredged material also poses unique problems.

Report: Schroeder, Paul R. 1981. "Chemical Clarification Methods for Confined Dredged Material Disposal," Draft Technical Report, U. S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Subject: Chemical clarification of dredged material containment area effluents.

Description: Laboratory and design procedures have been developed for chemical clarification of dredged material containment area effluents based on results of laboratory and field tests. The design is suitable for normal disposal operations including remote locations, high and variable flows and solids loadings, and temporary and intermittent operation. The treatment system requires minimal equipment and operation. Low viscosity highly cationic liquid polymer is applied at the drainage structure of the primary containment cell. Mixing for dispersing polymer and flocculation is provided by turbulence of flow through the discharge culvert. A small secondary cell is used for settling and storage of treated material. Moderately high molecular weight, highly cationic polyamines have performed well on the suspensions tested which ranged in solids concentration from 0.21 g/ℓ to 2.1 g/ℓ. Major cost components are polymer, labor, and construction. The cost for equipment, labor, and polymer should range from $\$0.08-0.25/yd^3$ ($\$0.10-0.33/m^3$) (1981 dollars) of in situ sediment dredged and is

dependent on the production rate, polymer dosage, and treatment system design.

The references listed at the end of Part VI under Ion Exchange show the many uses of ion exchange technique in the metal processing/plating industry, treating acid mine drainage and process of potable water supplies.

Neutralization

The need for neutralization of a water or soil that is contaminated with a high acidic or high alkaline waste may arise during the remedial action program. The review did not turn up much data on the subject, perhaps because of the relative simplicity of the process. Chen and Barber prepared an article that deals with neutralization of waste streams that contain toxic materials from a variety of industries. A review follows:

Article: Chen, K. Y., and Barber, N. R. 1977. "Sodium Bicarbonate Treats Acidic Industrial Water," Industrial Wastes, Vol. 23, No. 3, May/June 1977, p. 30, Scranton Gillette Communications, Inc., 434 S. Wabash Avenue, Chicago, IL.

Subject: Neutralization.

Description: This article describes treatment of acidic wastes such as those from coke plants, steel mills, plating works, etc. These wastes having pH's of 4 or so can be treated with sodium bicarbonate, a base having adequate reserve buffering capacity to hold the pH steady. This buffering capacity is lacking in other strongly basic chemicals such as lime and sodium hydroxide. Sodium bicarbonate is economical for pH's above 4.3, while wastes with lower pH's could be treated more economically by using other bases. Sodium bicarbonate will hold the pH between 6 and 9, which is the pH range in which toxic metals would precipitate.

Stripping

This process has been used successfully in treating effluents from pulping, urea manufacturing and munitions manufacturing plants, for chloride removal, and treating a variety of organic pollutants including PCB's. Two reviews are included, and other references are listed at the end of Part VI.

Article: Hwang, S. T., and Fahrenthold, P. 1980. "Treatability of the Organic Priority Pollutants by Steam Stripping," Water-1979, AIChE Symp. Ser., 76, 197, 37.

Subject: Stripping -- Organics.

Description: The use of steam stripping to remove organic priority pollutants was studied by Hwang and Fahrenthold. Steam stripping was found to be advantageous where it was difficult to provide removal by ordinary distillation because of high temperatures required for vaporization. Steam stripping was capable of providing effluent concentrations from 1 to 50 μg/l for many organic toxic pollutants. Effluent levels of 1 to 50 μg/l for condensed aromatics, 1 μg/l for PCBs, 4 μg/l for butylbenzyl phthalate, and 6 μg/l for dioctyl phthalate were achieved. Steam stripping was particularly effective in treating toxic pollutants having high activity coefficients and moderate vapor pressures.

Article: Berkau, E. E., et al. 1980. "A Scientific Approach to the Identification and Control of Toxic Chemicals in Industrial Wastewaters," Water-1979, AIChE Symp. Ser., 76, 197, 1.

Subject: Stripping.

Description: A program was developed to define the treatability of the 129 toxic pollutants and to provide the capability to predict, for specific or classes of chemicals, the optimum treatment sequence considering cost and degree of treatment. The toxics were divided into 7 groups:

(1) Aromatics

(2) Phenols

(3) Halogenated aliphatic hydrocarbons

(4) Ethers

(5) PNA's

(6) Phthalates

(7) Miscellaneous

Initial work was begun on the aromatics group. Treatment steps being examined included steam stripping, carbon adsorption, biological treatment, and synthetic resins.

Chemical oxidation

The process is a useful method for treating industrial waste from petroleum refineries, phenols, cresols and pesticide production, munitions manufacturing, textiles, pulp and tannery plants, electroplating operations, and phosphate production. It is also used in the production

of potable water supplies. This process warrants first consideration for waste not amenable to treatment by other means and as a system for removing residual traces of priority pollutants. The oxidation most frequently referred to in recent literature is ozonation. However, hydrogen peroxide, chlorine, chlorine dioxide and other oxidation are being used with a high degree of success. In today's technology chemical oxidants are often used in combination with photolysis, and this will be discussed under the heading Photolysis. Reviews of four articles dealing with four different chemical oxidants are reviewed and other references are listed.

Article: Robson, C. M. 1979. "Ozone's Many Applications Expands Its Image," Water and Sew. Works, 126, Ref. No. R-130.

Subject: Ozone applications.

Description: Robson summarized the latest information on ozone and its application to water treatment. A detailed discussion was included of each piece of equipment, the instrumentation involved, the parameters to be monitored, and five different tests for ozone residual.

Article: Perkins, W. S., et al. 1980. "Renovation of Dyebath Water by Chlorination and Ozonation - Part 1: Reactions of Dyes." Jour. Amer. Assoc. Textile Chemists and Colorists, 12, 182.

Subject: Chlorination - ozonation.

Description: Perkins et al. investigated the use of chlorine and ozone for renovation of dyebath water to permit reuse. Reactive and acid dyes responded very readily and were decolorized almost completely by chlorine or ozone. Direct and disperse dyes reacted much more slowly and were decolorized to a greater extent with ozone than with chlorine. The decolorization rate with chlorine increased at lower pH values, but pH had little or no effect on the reaction of ozone. Both chlorine and ozone were found to attack amide and other linkages and azo groups in the dye molecules.

Article: Keating, Edward J., Brown, Richard A., Greenberg, Edward S. 1978. "Phenolic Problems Solved with Hydrogen Peroxide Oxidation," Industrial Water Engineering, Dec, V15, N7, P22.

Subject: Hydrogen peroxide.

Description: Major industrial sources of phenolic waste discharges are: insulation fiberglass manufacturing, petroleum refineries, smelting and slag operations, organic products manufacture, synthetic resin manufacture, textile mills, steel-making, paint stripping, plywood hardboard, and wood preserving. Phenolic discharges create problems in three areas: toxicity to marine life, taste and odor disturbances, and oxygen depletion of the receiving water. Methods for analyzing phenols are described. Metal catalyzed hydrogen peroxide is evaluated as an oxidant for the destruction of phenols. Hydrogen peroxide treatment of phenols is shown to be commercially useful in batch treatment of phenolic wastes, for emergency backup to other phenolic treatment systems, and for polishing when discharge requirements are particularly stringent.

Article: Rauh, James S. 1979. "Disinfection and Oxidation of Wastes by Chlorine Dioxide, J. Env. Sciences, Mar-Apr, V22, N2, P42.

Subject: Chlorine dioxide (ClO_2).

Description: The use of chlorine dioxide as a disinfectant and a chemical oxidized in wastewater treatment is assessed. The history of ClO_2 research and development is reviewed. ClO_2 can be generated by adding a mineral acid to a sodium chlorite solution. Uses of ClO_2 in disinfection, odor control, and pollution control are described. ClO_2 can be used over a wide pH range for biocontrol, the control of industrial odors, and the oxidizing of wastewater contaminants. The potential for onsite generation of ClO_2 makes it a logical choice when considering wastewater treatment alternatives.

Biological Processes

The biological processes normally associated with wastewater treatment are adversely affected by many of the toxic and hazardous material that field personnel will encounter during the Superfund program. However, some systems may prove useful. This bibliography contains reviews and references on:

a. Activated sludge.

b. Lagoons.

c. Oxidation ditches.

d. Rotating biological contactor.

e. Trickling filters.

Activated sludge

This biological process has some applications to problems that may be encountered in cleanup operations. The EPA has funded research designed to access the feasibility of this process for treatment of organic priority pollutants and simulated landfill leachate. Reviews of articles on these projects are included. Other references were reviewed showing the application of this process in handling petroleum refinery and pesticide manufacturing waste. The use of powdered activated carbon to enhance the efficiency of this process is also covered.

Article: Cummins, M. 1981. "Effect of Sanitary Landfill Leachate on the Activated Sludge Process," presented at the 7th Annual Research Symposium on Land Disposal of Municipal Solid and Hazardous Waste and Resource Recovery, Municipal Environmental Research Laboratory, Office of Research and Development, U. S. EPA, Cincinnati, OH.

Subject: Activated sludge.

Description: Synthetic sanitary landfill leachate was spiked into a conventionally designed activated sludge wastewater treatment plant and the process control problems evaluated. The synthetic leachate simulated high organic strength, 20,000 mg/l COD excreted from a young landfill. The monitoring of the activated sludge process included oxygen uptake rate, mix liquor solids, specific oxygen utilization, sludge settling characteristic, and sludge production. The limiting factor in treating leachate was found to be sludge bulking.

Article: Petrasek, A., et al. 1980. "Behavior of Selected Organic Compounds in Wastewater Collection and Treatment Systems," Presented at the 53rd Annual Conference of the Water Pollution Control Federation, September 28-October 3, 1980, Las Vegas, NV, Water Pollution Control Federation, 2626 Pennsylvania Ave., N.W., Washington, DC.

Subject: Activated sludge.

Description: The major objective of this research effort was to evaluate the behavior of the organic "priority pollutants" in conventional wastewater collection and treatment systems.

For the purpose of research efficiency, the organic chemicals on the priority pollutant list were segregated into two general categories: i.e., those chemicals which are volatile and those organic compounds which are semivolatile or "nonvolatile."

This paper presented a study of the behavior of the semivolatile and nonvolatile organic priority pollutants.

The basic engineering approach used in the project was to operate two parallel sequences of unit processes. While one treatment train was operated as a control, in the experimental sequence the 23 organic compounds being studied were continuously added to the influent flow. This continuous spiking provided an initial concentration of 50 micrograms/liter for each compound being studied. All process flows and sludges were sampled so that the behavior of the chemicals being studied could be quantitated.

The sequence of unit processes studied consisted of a simulated sewer, a grit chamber, primary sedimentation, conventional activated sludge, and chlorination. The design flow for all processes was 1.5 gallons per minute.

This paper presents results obtained from the research effort and discusses the analytical procedures utilized during the project.

Report: Dojlido, Jan R. 1979. "Investigations of Biodegradability and Toxicity of Organic Compounds, Department of Water Chemistry and Biology," EPA-600/2-79-163, Municipal Environmental Research Laboratory, Warsaw, Poland, U. S. Environmental Protection Agency, Cincinnati, OH.

Subject: Activated sludge.

Description: The biodegradability and toxicity of the following organic compounds were investigated:

(1) Methylethyl ketone (MEK)

(2) Dimethyl amine (DMA)

(3) Dimethyl formamide (DMF)

(4) P-nitrophenol (PNP)

(5) O-chlorophenol (OCP)

(6) Trichlorophenol (TCP)

(7) Dichlorodiethyl ether (DCDEE)

(8) Five various fluoroscent whitening agents (FWA), all of the same stilbene-cyanuric type, but with different substitutes

Investigations of biodegradability were carried out by three methods, namely: (1) respirometric measurements, (2) tests in the river water, and (3) laboratory activated sludge units.

MEK, DMA, DMF, PNP, OCP, and TCP were all biodegradable. DCDEE was found to be a biologically inert substance under conditions of the tests. DCDEE is a volatile substance; therefore, it may be partially blown off in the aeration chamber. The FWA's are

fairly resistant to biodegradation; however, they do not affect the overall treatability of wastewater.

Long-term respirometric measurements using a "Sapromat" that prints out the amount of oxygen uptake every hour was very useful in supplying data for kinetic parameters and inhibiting effects of various compounds. The activated sludge tests gave overall treatability information and time required for acclimatization.

The toxicities of the test substances were determined by bioassays using fish Lebistes reticulatus and Daphnia magna. The toxicity to fish of MEK, DMF, and TCP are low, while PNP, OCP, and TCP were fairly high. The FWA's varied from low to high toxicity to fish depending on the molecular structure.

Lagoons

Lagoons are usually described as aerobic, anaerobic, or facultative, and they may be aerated or nonaerated. In truth many lagoons have different processes occurring simultaneously, and the basic operational nature of a given system may vary because of changes in environmental and/or operational conditions.

Lagoons are being used to treat waste from a number of major industries including:

a. Petroleum refineries.

b. Chemical plants.

c. Meat and poultry processing plants.

d. Pesticide manufacturers.

e. Pulp mills.

Lagoons are also used to treat leachate from various landfills.

Some researchers have used a technique of harvesting biological production by lagoons as a means of cleaning up toxic and hazardous material. Neal in the review which follows discusses such a project. Wolverton of NASA demonstrated the effectiveness of waterhyacinths in the uptake of toxic materials from industrial wastewater; he, like many others, then faced the problem of disposal of their biological harvest.

Many of the success stories with use of lagoons in industry do not appear frequently in the literature because of industries' fear of publicity in this area. A series of reviews that cover a cross section of articles on industrial application are included.

Article: Narum, O. A., and Moeller, D. J. 1977. "Water Quality Protection at the Simpson Paper Company, Shaster Mill." In: Preprinted Proceedings, TAPPI Environmental Conference, Chicago, Illinois, April 25-27, 1977, TAPPI, Atlanta, GA, p. 106.

Subject: Lagoons -- aerated pulping waste.

Description: Narum and Moeller described a four-part program initiated by Simpson Paper Company to improve wastewater treatment at its integrated bleached kraft pulp and paper mill near Anderson, Calif. The program included greater internal reuse of process water, upgrading existing primary treatment facilities, a new low rate aerated stabilization basin as a secondary waste treatment system, and use of the secondary effluent for irrigation of grain crops.

Article: Neil, J. H. 1976, 1977. "The Harvest of Biological Production as a Means of Improving Effluents from Sewage Lagoons," Research Rpt. 38, Can-Ont. Agreement Great Lakes Water Qual. (Can.) (1976); Poll. Abs., 8, 77-0035 (1977); Chem. Abs. 86, 194475c (1977).

Subject: Lagoons -- facultative-biological harvesting.

Description: The deliberate growth and harvesting of duckweed, daphnia, and midge larva as methods for upgrading lagoon effluents was examined by Neil, who concluded that these approaches were viable alternatives to chemical precipitation. Methods for increasing production and improving harvesting were discussed.

Articles: Ramalho, R. S. 1979. "Design of Aerobic Treatment Units." Hydrocarbon Process., 59, 10, 99.

Ramalho, R. S. 1979. "Design of Aerobic Treatment Units: 2. Aerated Lagoons and Wastewater Stabilization Ponds," Hydrocarbon Process., 59, 11, 285.

Ramalho, R. S. 1980. "Design of Aerobic Treatment Units: 3. Trickling Filters." Hydrocarbon Process., 60, 1, 159.

Subject: Activated sludge, lagoons, and trickling filters.

Description: Ramalho presented design recommendations and operational procedures for design of aerobic treatment units (activated sludge, trickling filters, and aerated lagoons and stabilization ponds) for treatment of refinery wastewaters.

Article: Olsen, R. J., et al. 1976. "Biological Waste Stabilization Ponds at Exxon's Baytown Refinery and Chemical Plant: System Performance and Algal Activity," Proc. 31st Ind. Waste Conf., Purdue Univ., 863, Ann Arbor Science Publishers, Ann Arbor, MI.

Subject: Petroleum refinery and chemical plant.

Description: The performance of an aerated lagoon followed by three large oxidation cells at a refinery and chemical plant located in Baytown, Tex., was reviewed by Olsen et al. This system produced an effluent equivalent to the expected performance of an activated sludge plant treating the same type of waste. Extensive algal data were reported for these ponds.

Anaerobic digestors

This process has a wide range of tolerance to many toxic materials and can handle some trace metals without system failure. In addition, properly designed and operated systems can produce useful biogases in sufficient quantities to warrant the installation of this option. The reviews included cover applications in the food processing industry, liquor distilleries, halogenated hydrocarbon disposal, treatment of landfill leachate with relatively high concentrations of heavy metals, and treatment of waste from rubber manufacturing operations.

Article: Benson, E. H., and Hunter, J. V. 1977. "Comparative Effects of Halogenated Hydrocarbon Solvents on Waste Disposal Processes," Proc. 31st Ind. Waste Conf., Purdue Univ., Ann Arbor Science Publishers, Inc., Ann Arbor, MI, 614.

Subject: Anaerobic treatment -- halogenated hydrocarbons.

Description: Threshold toxic concentrations of 0.4, 4.8, and 70.0 mg/l for trichloroethane, trichlorotrifluoroethane, and tetrachloroethylene, respectively, were found for batch-type laboratory anaerobic digestors. Efficient mixing and gas recirculation could air-strip some of the halocarbons from the sludge to prevent toxicity.

Article: Cameron, R. D. et al. 1980. "Trace Metals and Anaerobic Digestion of Leachate," Journal Water Pollution Control Federation, Vol. 52, No. 2, pp. 282-292. Pennsylvania Ave., N.W., Washington, DC.

Subject: Anaerobic digestion of leachate.

Description: Laboratory-scale studies demonstrated that anaerobic digestion applied to the treatment of a medium-strength leachate was a suitable and effective means of biostabilization, removing up to 97 percent of the biochemical oxygen demand and over 80 percent of the chemical oxygen demand. Treatment processes were not affected by the presence of heavy metals and other toxic substances contained in leachate feed as determined by an analysis of

kinetic coefficients. Trace metals removed during treatment included greater than 85 percent of the aluminum, barium, cadmium, mercury, nickel, and zinc and from 40 to 70 percent of the chromium, copper, lead, and manganese. These were mainly associated with digested sludge solids as either insoluble precipitates or organically bound complexes. Other trace metals such as calcium, magnesium, potassium, and sodium pass through the treatment process with little or no removal.

Article: Letting, G., et al. 1979. "Feasibility of Upflow Anaerobic Sludge Blanket (UASB) Process," Proceedings of the 1979 National Conference on Environmental Engineering, American Society of Civil Engineers, pp. 35–45, New York, NY.

Subject: Anaerobic digestion — food processing.

Description: An Upflow Anaerobic Sludge Blanket Process used in converting biodegradable, soluble, organic pollutants in industrial wastewaters to a directly burnable biogas composed mainly of methane has been developed, tested, and commercially applied in Holland. Operations on wastewater from the processing of sugar beets have shown hydraulic retention times of less than 10 hr, with reactor loadings of at least 10 kg COD per cu m digester volume per day and purification efficiencies exceeding 90 percent. Biogas production is at a rate of about 1 therm (100,000 BTU) per 10 Kg COD treated.

The set of conditions required for efficient operation of this anaerobic process is discussed. The process allows for tolerance of swings in pH (6–8) at relatively low temperatures (32° C–38° C) which can be readily achieved from most wastewater streams with little expenditure of additional energy. Sludge production is low, only about 5 percent of the COD loading, greatly alleviating disposal problems. These characteristics are conducive to the use of the anaerobic process to recover energy from a variety of wastewaters rich in carbohydrate-type substances produced routinely as a byproduct of many types of food processing activities.

Article: Obarsky, B. J., et al. 1979. "Sulfur Removal of Polysulfide Rubber Manufacturing Wastewaters by Anaerobic Treatment." Proc. 33rd Ind. Waste Conf., Purdue Univ., Ann Arbor Science Publishers, Mich., 402.

Subject: Anaerobic digestion — rubber manufacturing waste.

Description: Sulfur removals between 40 and 80 percent were achieved by anaerobic treatment of polysurfide rubber manufacturing wastes. Sulfate was noninhibitory until concentrations exceeded 2200 mg/l.

Article: Shea, T., et al. 1974. "Rum Distillery Slops Treatment by Anaerobic Contact Process." Environmental Protection Technology Series, U. S. EPA Office of Research and Development. EPA 660/2-74-074, U. S. Govt. Printing Office, Washington, DC.

Subject: Anaerobic treatment — distillery waste.

Description: The results of a one-year pilot scale study indicate the feasibility of the anaerobic contact process for treatment of rum distillery slops as follows:

(1) Capability to produce an effluent containing less than 30 g/l of COD at solids retention times greater than 40 days, in the treatment of a slops stream containing from 70 to 100 g/l of COD.

(2) Range of total annual costs (including amortized, operating, and maintenance costs) varying from \$3.74 per cu m treated at a design capacity of 190 cu m/day (\$14.18 per 1,000 gallons at 50,000 gpd) to \$2.13 per cu m treated at a design capacity of 1,140 cu m/day (\$8.07 per 1,000 gallons at 300,000 gpd).

(3) The recovery of methane as an energy byproduct of anaerobic contact treatment of rum distillery slops can, at current energy costs, reduce the above unit treatment costs from one-third at the 190-cu m/day (50,000-gpd) capacity to two-thirds at the 1,140-cu m/day (300,000-gpd) capacity.

Trickling filters

These systems have seen limited application in treating certain petro-refinery and phenolic wastewaters.

Article: Joyce, T. W. 1977. "Design Criteria for Phenol Treatment by Plastic Media Trickling Filters." Water--1976: II. Biological Wastewater Treatment, Amer. Inst. Chem. Engr. Symp. Ser., 73, 167, 160.

Subject: Trickling filters — phenols.

Description: Joyce presented modifications to the design equation commonly used for sizing plastic media trickling filters based on case histories of phenol containing wastewater treatment.

Rotating biological contactors

These systems have been used in treatment of refinery and munitions manufacturing wastewater as well as domestic waste. Three reviews of industrial application are included.

Article: Dehnert, J. F. 1978. "The Use of Powdered Activated Carbon with Rotating Biological Surface for Refinery Wastewater

Treatment," presented at Wastewater Equipment Manufacturer's Association 6th Annual Industrial Pollution Conf., St. Louis, Mo., Apr. 10-13, 78, p. 507.

Subject: Rotating biological contactors — refinery waste.

Description: A supplemental petroleum refinery wastewater treatment plant utilizing powdered activated carbon in conjunction with a rotating biological surface unit was developed to help meet the stringent emission regulations that went into effect in July 1977. Pilot plant studies were conducted to compare performances of activated sludge, trickling filters, and activated carbon absorption processes in treating refinery wastewater. Construction of the new facilities began in January 1977. The two selected treatment processes are combined within the rotating disc units. Solid removal equipment, necessary for the disc units, handles both the biological solids produced from the rotating biological units and the spent powdered carbon.

Article: Knowlton, H. E. 1977. "Biodisks Work in Wastewater Treating." Oil and Gas Jour., 75, 40, 86.

Subject: Rotating biological contactors — refinery waste.

Description: Knowlton covered the current usage of rotating biological treatment units for the treatment of petroleum refinery wastewaters. Operating experiences in four refineries using disk units, either as sole biological treaters, or in combination with aerated ponds, were presented. Performance data for one refinery was included. Biomass development required from 1 to 7 weeks, in accordance with decreasing process wastewater temperature.

Article: Smith, L. L., and Zeigler, E., Jr. 1979. "Biological Treatment of a Munitions Manufacturing Facility Wastewater," Proc. 33rd Ind. Waste Conf., Purdue Univ., Ann Arbor Science Publishers, MI, 432.

Subject: Rotating biological contactors — munitions wastes.

Description: Pilot biological studies were conducted for highly variable Radford munitions plant wastewater containing ethanol, ethyl ether, acetone, and traces of nitroglycerin and miscellaneous propellant ingredients. A rotating biological surface process (Bio-Surf) was recommended over activated sludge because it responded better to wastewater variability.

Thermal Processes

The thermal destruction of toxic and hazardous substances is normally an expensive process but may be the only acceptable alternative in certain situations. The processes discussed herein are:

a. Pyrolysis.

b. Wet air oxidation.

c. Incineration.

Pyrolysis

This process is basically incineration in an air-starved environment. The three reviews included cover summary of the EPA's research in this area up to 1978, the economics of these systems, and suggestion for converting incinerators to pyrolytic systems.

Article: Dandeneau, D. E., et al. 1979. "Modernizing Thermal Sludge Disposal: Conversion of Existing Incinerators to Pyrolytic Systems," Paper given at the 52nd Annual Conference of the Water Pollution Control Federation, October 7-12, 1979, Houston, TX, Water Pollution Control Federation, 2626 Pennsylvania Avenue, N.W., Washington, DC.

Subject: Pyrolysis -- incinerator conversion.

Description: The benefits derived by thermal disposal of sewage sludge (elimination of known and unknown pathogens and organic toxins, volume, and weight reduction, etc.) can be obtained in an environmentally sound and cost effective manner by modernizing existing sludge incinerators.

The equipment changes that should be considered when modernizing are: improved dewatering; better furnace feed control; and improved control of the combustion process. Each is discussed in terms of its beneficial effect.

Modernization of the thermal process itself, from incineration to starved air combustion (pyrolysis), is discussed in terms of what changes might have to be made to existing furnaces that would enable them to operate in the starved air combustion mode and what the benefits of that conversion would be. A comparison of incineration and starved air combustion is made with special emphasis given to fuel and power consumption. The ability of the starved air combustion (pyrolysis) furnace to produce less than 1.3 lb of emissions per ton of dry feed and to have less than 250 tpy uncontrolled and 50 tpy controlled emissions at large throughput rates is discussed.

Article: Huffman, G. L. et al. 1978. "EPA's R&D Program in Pyrolytic Conversion of Wastes to Fuel Products," American Chemical Society-Division of Environmental Chemistry, Vol. 18, No. 1; 175th National Meeting, March 12-17, 1978, pp. 415-417, Energy Resources Company, 185 Alewife Brook Parkway, Cambridge, MA.

Subject: Pyrolysis — research and development summary.

Description: The article provides a summary of projects currently sponsored by U.S. EPA related to thermochemical conversion of wastes to fuel products. Four projects are described briefly:

(1) Pilot-scale pyrolysis of mixed wastes to fuel gas, fuel oil, and char in a fluidized bed reactor (Energy Resources Company)

(2) Bench-scale steam gasification of agricultural and feedlot wastes to energy products

(3) Lab tests on a molten salt catalytic technique to convert discarded tires into fuels

(4) Bench-scale development of a noncatalytic process that transforms pyrolysis off-gases into polymer gasoline

It is felt that these are rather innovative technologies with a potential for interchange of feedstocks and methods of conversion into usable fuel products.

Article: Richmond, C. A., et al. 1978. "Economics Associated with Waste or Biomass Pyrolysis Systems," American Chemical Society-Division of Environmental Chemistry, Vol. 18, No. 1, 175th National Meeting, March 12-17, 1978, pp. 359-360, Energy Resources Company, 185 Alewife Brook Parkway, Cambridge, MA.

Subject: Pyrolysis — system economics.

Description: The article briefly summarizes work done on a study of the economics of pyrolysis. The study covers various processes for the use of the produced gas to produce heat, work, or electricity.

The economic analysis includes the following:

(1) Transportation of waste to conversion facility

(2) Conversion of waste to gas

(3) Fuel gas cleanup system

(4) Transportation of fuel gas to consumer

(5) Retrofit of combustion equipment to handle the fuel gas

It is suggested that economics of scale do not apply in many cases for fuel gas systems because larger size requires longer transportation distances for the product gas and feed materials.

Wet air oxidation (WAO)

WAO is a mobile process for management of a variety of dilute toxic and hazardous wastewaters. The three article reviews shown discuss destruction of PCB's, halogenated pesticides, chemical warfare agents, explosives, propellants, and some inorganic compounds.

Article: Wilhelmi, A. R., and Knopp, P. V. 1978. "Wet Oxidation as an Alternative to Incineration," presented at the 71st Annual Meeting of the American Institute of Chemical Engineers, Nov. 12-16, 1978. Zimpro, Inc., Environmental Control Systems Subsidiary of Sterling Drug, Inc., Rothschild, WI.

Subject: WAO of Hazardous and Toxic Wastewaters.

Description: WAO offers a unique alternative to conventional incineration for the destruction and detoxification of dilute hazardous and toxic wastewaters and in some instances opportunities for inorganic chemical recovery as well as energy recovery.

Wastewater is pumped through a heat exchanger to a temperature such that when the wastewater and a near stoichiometric quantity of compressed air enter the reactor, the exothermic heat of reaction of the oxygen-demanding components in the waste and the supplied oxygen raise the mixture temperature to the desired maximum. The reactor effluent then serves as the heat exchanger medium for the raw wastewater. The pressure is then let down through a control valve, and the phases separated.

Cost comparisons between conventional incineration and WAO indicate that WAO is somewhat greater in capital cost but considerably less expensive to operate. Total operating costs including amortization favor WAO when the fuel value of the waste organics is low (less than approximately 50 g/1 COD).

Article: Edwards, B. H., and Paullin, J. N. 1980. "Emerging Technologies for the Destruction of Hazardous Wastes--Molten Salt Combustion." In Shultz, D., and Black, D., Treatment of Hazardous Waste: Proceedings of the Sixth Annual Research Symposium, EPA-600/9-80-011, U. S. Environmental Protection Agency, Washington, DC, p. 77.

Subject: Wet oxidation.

Description: Ebon Research Systems is investigating new technologies for disposal of hazardous wastes. These methods are not state of the art but involve new technologies or a novel variation of an established technology. Some of the processes that have been studied are: fluidized bed combustion, molten sodium combustion, high energy electron bombardment, ultraviolet radiation with hydrogen, molten salt combustion, and various combinations of

ozonation, chlorinolysis, and ultraviolet radiation. Molten salt combustion is discussed in detail. Materials are incinerated, in the presence of oxygen, beneath or on the surface of a pool of molten salts. Alkali salts such as a mixture of sodium carbonate and sodium sulfate are usually used, but the salt in the melt can be varied to suit the properties of the waste. The operation of bench-scale and pilot-plant combustors is discussed. Pesticides, chemical warfare agents, PCB's, explosives, and propellants are some of the hazardous compounds which have been almost completely combusted using molten salts. Both high levels of particulates and undesirable emissions from organophosphorus and arsenical compounds cause problems in the process.

Article: Pytlewoki, L. L., et al. 1980. "The Reaction of PCB's with Sodium, Oxygen, and Polyethylene Glycols." In Shultz, D., and Black, D., Treatment of Hazardous Waste: Proceedings of the Sixth Annual Research Symposium, EPA-600/9-80-011, U. S. Environmental Protection Agency, Washington, DC, p. 72.

Subject: Wet oxidation.

Description: PCB's, as well as representative halogenated pesticides, were found to be rapidly and completely decomposed by the use of molten sodium metal dispersed in polyethylene glycols. The reaction was found to be exothermic and self-sustaining with the formation of NaCl, H_2, and polyhydroxylated biphenyls (in the case of PCB's) and other phenolic compounds. The reaction requires the presence of sodium and oxygen, with the subsequent formation of a sizeable number of free radicals. A superoxide type of free radical was identified by the use of electron spin resonance spectroscopy, and it is felt that dechlorination occurs by the reaction of a PCB molecule with a novel sodium-glycolate-superoxide radical. A reactive sodium-glycolate-oxygen solution can be made up beforehand, stored, and used effectively.

The experimental conditions are simple, open, and inexpensive. The reagents used are commonly known and available in commercial quantities. Cost estimates have been made for PCB's decomposition on a large scale and range between 10 and 30¢ per pound, without taking into account the salability of the reaction products.

Incineration

This is a viable process for disposal of toxic and hazardous waste during cleanup operation, and the use of mobile units has been considered. One drawback to the process is the management of the airborne pollutants that may be produced. Reviews of three articles covering a wide range of toxic materials are included.

Handbook: Bonner, T. A., et al. 1980. Engineering Handbook for Hazardous Waste Incineration. EPA Contract #68-03-3025. Work Directive SDM02, USEPA, Cincinnati, OH.

Subject: Incineration of hazardous waste.

Description: This handbook provides an overview of incineration systems for various types of waste. Commercially available technology, emerging technology, and foreign technology are included. Waste characterization is described. Detailed information and procedures for evaluation of design and operating conditions are given as well as economic factors involved in construction and operation.

Article: Freestone, F., and Brugger, J. 1980. "Incineration of Hazardous Wastes at Uncontrolled Dumpsites," presented at the EPA National Conference on Management of Uncontrolled Hazardous Waste Sites, Washington, D. C. October 1517, 1980, Hazardous Materials Control Research Institute, 9300 Columbia Blvd., Silver Springs, MD.

Subject: Incineration of PCB's, Kepone, DDT, Agent Orange, et al.

Description: U. S. EPA is currently developing a mobile system for high temperature incineration of organic hazardous wastes at spills and disposal site cleanups. Highway weight and size limitations, the EPA specifications for incineration of PCB's, and air pollution control requirements for particulates (such as phosphorous pentoxide), carbon monoxide, sulfur dioxide and hydrogen chloride constitute the primary design constraints. A rotary kiln and secondary combustion chamber design were selected.

Field operations are expected to be conducted in three phases: feedstock analysis and preparation, execution of a "burn," and concluding activities. Detoxification of Kepone, PCB's, DDT, organo-chlorine waste, and herbicide "Orange" is discussed.

Article: Fredotte, P. E., et al. 1980. "Chemical Suppression of Air Pollutants During the Thermal Disposal of Hazardous Wastes," paper presented at the 73rd Annual Meeting of the Air Pollution Control Association, June 22-27, 1980, 4400 5th Ave., Pittsburgh, PA.

Subject: Air pollution control -- hazardous waste incineration.

Description: A concept for the chemical suppression of air pollutants is presented and has been demonstrated to be technically feasible during the thermal disposal (pyrolysis-afterburner) of hazardous waste. It has been shown that chemical constituents such as chlorine, sulfur and phosphorus can be retained with the ash during the pyrolysis process. The degree of effectiveness

varies with the type and concentration of additive utilized. Within the parameters of the test program, sodium hydroxide exhibited a greater effectiveness than calcium hydroxide or either of the salts tested. Calcium hydroxide exhibited sufficient reactivity when compared to sodium hydroxide to warrant its use due to its lower cost, availability and ease of disposal.

Photolysis

The use of this process in wastewater treatment was a laboratory novelty until a few short years ago. However, it rapidly gained in popularity as researchers and designers began to recognize its treatment effectiveness. Most applications consist of bombardment with ultraviolet light coupled with the use of a strong oxidant such as ozone, hydrogen peroxide, or chlorine. WES began research studies on the application of this project to a series of problems at Rocky Mountain Arsenal (RMA) in 1976. A review follows.

Report: Buhts, R. E., Malone, P. G., and Thompson, D. W. 1978. "Evaluation of Ultraviolet/Ozone Treatment of Rocky Mountain Arsenal (RMA) Groundwater (Treatability Study)," TR Y-78-1, U. S. Army Engineer Waterways Experiment Station, P. O. Box 631, Vicksburg, MS.

Subject: Ultraviolet-ozone treatment.

Description: The groundwater at RMA is known to be contaminated with chlorinated hydrocarbons, organophosphorous, organosulfur, and other organic compounds. The purpose of this investigation was to determine the feasibility of using ultraviolet ozone (UV/O_3) treatment to reduce the concentration of those contaminants in the RMA groundwater.

This report discusses the experimental results obtained from treating RMA groundwater with UV light and ozone. The laboratory investigations used two different batch reactors and varied such parameters as ozone concentration, temperature, and wattage of UV light. Continuous flow experiments were also conducted. In batch experiments, total organic carbon removal ranged from 40 to 90 percent. The concentrations of diisopropylmethylphosphonate (DIMP) and other organic compounds were significantly reduced. In the continuous flow phase of the study, it was possible to remove 93 percent of the DIMP originally present and lower the levels of all other organic contaminants to below detectable limits.

Report: Barr, W. A. 1976. "An Evaluation of the Engineering Design Parameters of Hydrogen Peroxide Ultraviolet Oxidation of Refractories in Waste Water," Naval Academy, Annapolis, Md., Energy-Environment Study Group, USNA-EPRD-31.

Subject: Ultraviolet-hydrogen peroxide treatment.

Description: The capability of oxidizing refractories in wastewater in hydrogen peroxide ultraviolet treatment had been demonstrated by laboratory experiments. The purpose of this project was to determine data which will permit an engineer to design a full-scale hydrogen peroxide-ultraviolet treatment facility. These data were developed for this most difficult refractory, acetic acid/acetate, in wastewater, and these results show that the engineer may design for minimum-time or minimum-energy utilization.

Article: Mauk, C. E., and Prengle, H. W., Jr. 1976. "Ozone with Ultraviolet Light Provides Improved Chemical Oxidation of Refractory Organics," Pollution Engineering, 8(1), 42 (1976), Selected Water Resources Abstract, 9, W76-07742 (1976).

Subject: Ultraviolet ozone -- plating waste.

Description: Mauk and Prengle investigated the possibility of using ozone with ultraviolet light to treat electroplating wastewater and found that ultraviolet light enhanced the effect of ozone.

Other References

Physical treatment settling

Mendis, J. B., and Benedek, A. 1980. "Tube Settlers in Secondary Clarification of Domestic Wastewater," Jour. Water Poll. Control Fed., 52, 1893.

Zanker, A. 1980. "Nomographs Determine Settling Velocities for Solid-Liquid Systems," Chem. Eng., 87, 10, 147.

Filtration

Adin, A. 1978. "Solution of Granular Bed Filtration Equations," Jour. Environ. Eng. Div., Proc. Amer. Soc. Civil Eng., 104, 471.

Bowen, L. B., et al. 1977. "Zinc Recovery from Rayon Plant Sludge," Chem. Eng. Prog., 73, 5, 50.

George, A. P., and Chaudhuri, M. 1977. "Removal of Iron from Groundwater by Filtration through Coal," Jour. Amer. Water Works Assn., 69, 385.

Harris, S. E., et al. 1977 "Intermittent Sand Filtration for Upgrading Waste Stabilization Pond Effluents," Jour. Water Poll. Control Fed., 49, 83.

Metzner, A. V. 1979. "The Design and Sizing of Granular Media Filtration Systems for Industrial Waste Treatment," Proc. 33rd Ind. Wastes Conf., Purdue Univ., 1978, Ann Arbor Science, Ann Arbor, MI, 32.

Mechanical dewatering

Purchas, D. B., Ed. 1977. Solid/Liquid Separation Fquipment Scale-Up, Uplands Press Limited, Croydon, England.

Oil water separation

Erwin, D. 1977. Closed-Loop System Separated Oil from Prewash Overflow," Industrial Wastes, Vol. 23 (2), 1977. p. 26.

Gadjiev, V. G., and Chian, E. G. K. 1976. "Advanced Waste Treatment of Oily Wastewater." In: Proceedings of the 31st Industrial Waste Conference, Purdue University, Lafayette, IN. p. 965.

Hart, J. A. 1970. "Air Flotation Treatment and Reuse of Refinery Wastewater." In: Proceedings of the 25th Industrial Waste Conference, Purdue University, Lafayette, IN. p. 406.

Hart, J. A. 1973. "Wastewater Recycle or Use in Refinery Cooling Towers," The Oil and Gas Journal, Vol. 71 (24). p. 92.

Prober, R., et al. 1980. "Wastewater Treatment for New Oil Re-Refining Facilities: A Case History," Proc. 8th Annual WWEMA Ind. Poll. Conf., Houston, TX, 141 (1980).

Flotation

Beck, D., et al. 1979. "Foam Fractionation of Spent Sulphite Liquor Part II: Separation of Toxic Components," Canadian Jour. Chem. Eng. (Can.), 57, 327.

Betzer, N., et al. 1980. "Effluent Treatment and Algae Recovery by Ozone-Induced Flotation," Water Research (G. B.), 14, 1003.

Brasch, D. J., and Robilliard, K. R. 1979. "Rates of Continuous Foam Fractionation of Dilute Kraft Black Liquor," Sep. Sci. and Technol., 14, 699.

Bucsh, R. O., et al. 1980. "Ion-Precipitate Flotation of Iron-Cyanide Complexes," Jour. Water Poll. Control Fed., 52, 2925.

Franzen, A. E., et al. 1980. "Processing Refinery Wastewater by Coagulation and Flotation Following Biological Oxidation," EPA-600/2-80-047, NTIS No. PB80-142144.

French, R. M., and Wilson, D. J. 1980. "Fluid Mechanics - Foam Flotation Interactions," Sep. Sci. and Technol., 15, 1213.

Maddock, J. E. L., and Tomlinson, E. J. 1980. "The Clarification of Effluent from an Activated Sludge Treatment Plant Using Dissolved-Air Flotation," Water Poll. Control (G. B.), 79, 117.

Ramirez, E. R. 1980. "Comparative Physiochemical Study of Industrial Wastewater Treatment by Electrolytic Dispersed Air and Dissolved Air Flotation Technologies," Proc. 34th Ind. Waste Conf., Purdue Univ., Ext. Ser., 1979, 699.

Sato, Y., et al. 1979. "Removal of Emulsified Oil Particles by Dissolved Air Flotation," Jour. Chem. Eng. Japan (Jap.), 12, 454.

Sato, Y., et al. 1980. "Removal of Emulsified Oil Particles by Dissolved Air Flotation," Jour, Chem. Eng. Japan (Jap.), 13, 385.

Shannon, W. T., and Buisson, O. H. 1980. "Dissolved Air Flotation in Hot Water," Water Research (G. B.), 14, 759.

Takahashi, T., et al. 1979a. "Fundamental Study of Bubble Formation in Dissolved Air Pressure Flotation." Jour. Chem. Eng. Japan (Jap.), 12, 275 (1979).

Takahashi, T., et al. 1979b. "Separation of Oily Water by Bubble Column." Jour. Chem. Eng. Japan (Jap.), 12, 394.

Thackston, E. L., et al. 1980. "Lead Removal with Adsorbing Colloid Flotation," Jour. Water Poll. Control Fed., 52, 317.

Wilson, D. J., and Kennedy, R. M. 1979. "Electrical Aspects of Adsorbing Colloid Flotation, IX, Effects of Surfactant Overdosing." Sep. Sci. and Technol., 14, 319.

Zajic, J. E., et al. 1979. "Foam Fractionation of Spent Sulphite Liquor Part I: Separation of Surfactants," Canadian Jour. Chem. Eng. (Can.), 57, 321.

Evaporation

Alhgren, R. M. 1974. Water Reclamation from Industrial Uses, American Institute of Chemical Engineers Symposium Series, Vol. 70 (136). p. 539.

Blount, E. 1977. "Plater Meets Stringent Local Limits for Effluent with Help of Evaporator." Plat. Sur. Finish., 41, 2, 24-6.

Culotta, J. M., and Swanton, W. F. 1970. "Case Histories of Plating Waste Recovery Systems," Plating, Vol. 57, March 1970. p. 251.

Elicker, L. N., and Lacy, R. W. 1978. "Evaporative Recovery of Chromium Plating Rinse Waters," EPA 600/2-78-127, U. S. Environmental Protection Agency. 52 pp.

Egg, R. P., and Reddell, D. L. 1980. "Design of Evaporative Pits for Waste Pesticide Solution Disposal." In Shultz, D., and Black, D., Treatment of Hazardous Waste: Proceeding of the Sixth Annual Research Symposium, EPA-600/9-80-011, U. S. Environmental Protection Agency, Washington, DC. p. 88.

Fosberg, T. M. 1974. "Industrial Water Reclamation," American Institute of Chemical Engineers Symposium Series, Vol. 70 (136). p. 534.

Kolesar, T. J. 1972. "Closed-Loop Recycling of Plating Wastes," Industrial Finishing, Vol. 48 (9). p. 22.

Leker, J. E., and Parsons, W. C. 1973. "Recycling Water. A Simple Solution," Southern Pulp and Paper Manufacturer, Vol. 36 (1). p. 32.

Malakul, R. P. 1978. System for Recycling Water Soluble, e.g. Ethylene Glycol, Waste Liquids. U. S. Patent 4,080,247.

Niven, D. 1977. "Evaporators Save Silver from Production Barrel Plater," Industrial Finishing, Hitchcook Publishing, Wheaton, IL, March 1977.

U. S. EPA, 1979. "Control Technology for the Metal Finishing Industry -- Evaporators," Summary Report, Cincinnati, OH.

Reinenga, D. G. 1978. "Evaporative Process for Treatment of Phosphate-Containing Effluent," EPA-600/2-78-119, June 1978, Cincinnati, OH.

Shuckrow, A. J., Pajale, A. P., and Touhill, C. J. 1980. "Hazardous Waste Concentration Technologies." In Shultz, D., and Black, D., Treatment of Hazardous Waste: Proceeding of the Sixth Annual Research Symposium, EPA-600/9-80-011, U. S. Environmental Protection Agency, Washington, DC. p. 50.

Distillation

Burgress, T. L., and Voight, D. 1977. "Nekoosa Papers, Inc., Cleans Condensates with Steam Distillation." In: Preprints,

Environmental Improvement Conference, Canadian Pulp and Paper Association, Nov. 1-3, 1977, Moncton, New Brunswick (CPPA, Technical Section, Montreal). p. 19.

Kinder, R., et al. 1977. "Separation of Aromatic Hydrocarbons and Inorganic Impurities from the Wastewater of Petrochemical Synthesis Processes," Tech. Umweltschutz (E. Ger.), 13, 48 (1976). Chem. Abs., 87, 188840.

Land application

Anon. 1978. "The Place of Land Treatment of Wastewater in Today's Society," Civil Engineering, Vol. 48, No. 1, January 1978, pp. 78-81.

Brown, G. E. 1977. "Land Application of High Nitrogen Industrial Wastewater," Water--1976: Biological Wastewater Treatment, Amer. Inst. Chem. Engr. Symp. Ser., 73, 167, 227.

Crites, R. W., and Pound, C. E. 1976. "Land Treatment of Municipal Wastewater." Environ. Sci. and Technol., 10, 549.

Garrigan, G. A. 1977. "Land Application Guidelines for Sludges Contaminated with Toxic Elements," JWPCF, Dec. 1977, pp. 2580.

Karlen, D. L., et al. 1976. "Irrigation of Corn with Simulated Municipal Sewage Effluent," Jour. Environ. Quality, 5, 3, 269.

Katzenelson, E., and Teltch, B. 1976. "Dispersion of Enteric Bacteria by Spray Irrigation," Jour. Water Poll. Control Fed., 48, 710.

Sorber, C. A., et al. 1967. "A Study of Bacterial Aerosols at a Wastewater Irrigation Site." Jour. Water Poll. Control Fed., 48, 2367.

Fixation, stabilization, encapsulation

Bartos, M. J., and Palermo, M. R. 1977. "Physical and Engineering Properties of Hazardous Industrial Wastes and Sludges," U. S. Army Engineer Waterways Experiment Station, Vicksburg, MS, NTIS EPA-600/2-77-139.

Christensen, D. C., and Wakamiya, W. 1980. "A Solid Future for Solidification/Fixation Processes," Toxic and Hazardous Waste Disposal, Ann Arbor, p. 75.

Landreth, R. E., and Mahloch, J. L. 1977. "Chemical Fixation of Wastes." Ind. Water Eng., 14, 4, 16.

Mercer, R. B., Malone, P. G., and Broughton, J. D. 1978. "Land Disposal of Hazardous Wastes. Field Evaluation of Chemically Stabilized

Sludges," U. S. Army Engineer Waterways Experiment Station, Vicksburg, MS, NTIS EPA-600/9-78-016.

Malone, P. G., et al. 1981. "Estimation of Pollution Potential of Industrial Waste from Small-Scale-Column Leaching Studies." Presented at the Seventh Annual Research Symposium on Land Disposal of Municipal Solid and Hazardous Waste and Resource Recovery, Philadelphia, PA, March 16-18, 1981.

Ruckel, H. 1976. "Encapsulation of Toxic Wastes in Concrete Rings." In Solidification and Encapsulation of Waste Products for Storage Purposes, Conf. of Berlin, Sep 23-24.

Subramanian, R. V., et al. 1979. "Immobilization of Hazardous Residuals by Encapsulation, Final Technical Report," National Science Foundation, NTIS PB-296-642.

Petro-chemical

Berbenni, P., and Spigai, G. 1979. "Selection and Experimental Tests on the Treatment of Waste Water from the Production of Phenol Formaldehyde Resins," Inquinamento (It.), 20, 2, 25 (1978); Chem. Abs., 90, 28568.

Khalturina, T. I., et al. 1980. "Recirculation of Sediment in Petroleum-Containing Wastewater," Zhur. Priklad. Khim., 53, 533 (1980); Chem. Abs., 93, 119676 (1980).

Mason, W., and Allen, G. S. 1974. "How to Treat Polystyrene Wastes," Ind. Wastes, 22, 5, 31.

Carbon adsorption

Andren, R. K., et al. 1977. "Removing Explosives from Wastewater," Ind. Wastes, 23, 2, 28 (1977).

Boydaniak-Sulinska, W. 1978, 1979. "Dephenolization of Industrial Waste Water on the Macroporous Adsorbent Amberlite XAD-4." Environ. Prot. Eng., 4, 3, 201 (1978); Chem. Abs., 91, 44040 (1979).

El-Dib, M. A., and Badaway, M. I. 1979. "Adsorption of Soluble Aromatic Hydrocarbons on Granular Activated Carbon," Water Res. (G. B.), 13, 255.

Giusti, D. M., et al. 1974. "Activated Carbon Adsorption of Petrochemicals," Jour. Water Poll. Control Fed., 46, 947.

Hager, D. G. 1974. "Industrial Wastewater Treatment by Granular Activated Carbon," Ind. Water Eng., 11, 1, 14.

Heck, R. P. 1978. "Munitions Plant Uses Adsorption in Wastewater Treatment," Ind. Wastes, 24, 2, 35.

Lawrence, J., and Tosine, H. M. 1976. "Adsorption of Polychlorinated Biphenyls from Aqueous Solutions and Sewage," Environ. Sci. and Technol., 10, 381.

Shindala, A., and Bond, M. T. 1979. "Physical-Chemical Treatment of Wastewaters Generated from the Production of Dinitro Butyl Phenol and Bladex," Proc. 33rd Ind. Waste Conf., Purdue Univ., Ann Arbor Science Publishers, Mich., 335.

Szachta, J. M. 1978. "Analysis of Carbon Versus Resin," NTIS, AD-A053 863/7WP.

van Vliet, B. M., et al. 1980. "Modeling and Prediction of Specific Compound Adsorption by Activated Carbon and Synthetic Adsorbents," Water Research (G. B.), 14, 1719.

Wroniewicz, V. S. 1978. "Controlling Chlorinated Benzene Compounds in Plant Waste Waters," Poll. Eng., 10, 11, 43.

Membrane Separation

Bansal, I. K. 1976. "Concentration of Oily and Latex Wastewaters Using Ultrafiltration Inorganic Membranes," Ind. Water Eng., 13, 5, 6.

Beder, H., and Gillespie, W. J. 1970. "Removal of Solutes from Mill Effluents by Reverse Osmosis," TAPPI, Vol. 53, 1970. p. 883.

Bhattacharyya, D., et al. 1977. "Membrane Ultrafiltration of Nitrotoluenes from Industrial Wastes," Proc. 31st Ind. Waste Conf., Purdue Univ., (Ann Arbor Science Publishers, Inc., Ann Arbor, MI) 1976, 139.

Bhattacharyya, D., et al. 1979. "Ultrafiltration Characteristics of Oil-Detergent-Water Systems: Membrane Fouling Mechanisms," Sep. Sci. and Technol., 14, 529.

Chian, E. S. K., and Fang, H. H. P. 1974. "Evaluation of New Reverse Osmosis Membranes for the Separation of Toxic Compounds from Water," Amer. Inst. Chem. Eng. Symp. Ser., Water--1973, 70, 136, 497.

Dochi, Y., and Takizawa, A. 1980. "Advanced Treatment of Petroleum Plant Wastewater and Water Recovery," Kagaku Gijutsushi Mol., 18, 53 (1980); Chem. Abs., 93, 79111 (1980).

Fang, H. H., and Chian, E. S. 1976. "Reverse Osmosis Separation of Polar Organic Compounds in Aqueous Solution." Environ. Sci. and Technol., 10, 364.

Fremont, H. A., Tate, D. C., and Goldsmith, R. L. 1973. "Color Removal from Kraft Mill Effluents by Ultrafiltration," EPA 660/2-73-019," U. S. Environmental Protection Agency. 240 pp.

Haagensen, U. 1977. "Reverse Osmosis and Ultrafiltration Applied to the Pulp Industry," Papier Carton Cellulose (Fr.), 26, 4, 46 (Apr 1977); Abs. Bul. Inst. Pap. Chem., 48, 4, 3795 (Oct 1977).

Kosarek, L. J. 1979. "Water Reclamation and Reuse in the Power, Petrochemical Processing, and Mining Industries," Proc. Water Reuse Symposium, Washington, DC. 1979, 1, 421.

Kremen, S. S., Hayes, C., and Dubos, M. 1977. "Large-Scale Reverse Osmosis Processing of Metal Finishing Wastewaters," Desalination (G. B.), Vol. 20, 1977. p. 71.

Lopez, C. X., and Johnson, R. 1978. "Industrial Wastewater Recycling with Ultrafiltration and Reverse Osmosis." Proceedings of the 32nd Industrial Waste Conference, Purdue University, Lafayette, IN, 1978. p. 81.

Matsuura, T., and Sourirajan, S. 1978. "Characterization of Membrane Material, Specification of Membranes, and Predictability of Membrane Performance in Reverse Osmosis," Ind. and Eng. Chem. Process Design and Development, 17, 419.

Nazarov, V. I., et al. 1979. "Refinery Wastewater Desalting by Means of Reverse Osmosis." Chem. Tech. Fuels and Oils, 15, 3-4, 278. (Translated 1980).

North Star Research and Development Institute. 1971. Ultrathin Membranes for Treating Metal Finishing Effluents by Reverse Osmosis. EPA 12010 DRH--11/71, U. S. Environmental Protection Agency. 92 pp.

Peterson, R. J., and Cobian, K. E. 1976. "Reverse Osmosis Recycle of Electroplating Chemicals at pH Extremes," Plating and Surface Finishing, 63(6), 51.

Quinn, R. M., and Hendershaw, W. K. 1976. "A Comparison of Current Membrane Systems Used in Ultrafiltration and Reverse Osmosis," Ind. Water Eng., 13, 3, 12.

Zeitoun, M. A., Roorda, C. A., and Power, G. R. 1979. "Total Recycle Systems for Petrochemical Waste Brines Containing Refractory Contaminants," EPA600/2-79-021, U. S. Environmental Protection Agency. 98 pp.

Chlorination

Harrison, R. B., and Haddock, J. K. 1977. "Chlorination Seems Best for Removing Suspended Solids from Lagoon Effluents," Water and Wastes Engr., 14, 5, 48.

Oliver, B. G., and Carey, J. H. 1977. "Photochemical Production of Chlorinated Organics in Aqueous Solutions Containing Chlorine," Environ. Sci. and Technol., 11, 893.

Perkins, W. S., et al. 1980. "Renovation of Dyebath Water by Chlorination and Ozonation--Part 1: Reactions of Dyes," Jour. Amer. Assoc. Textile Chemists and Colorists, 12, 182.

Saunier, B. M., and Selleck, R. E. 1979. "The Kinetics of Breakpoint Chlorination in Continuous Flow Systems," Jour. Amer. Water Works Assn., 71, 164.

Ion exchange

Bennett, D. L. 1978. "The Efficiency of Water Treatment Processes in Radium Removal," Jour. Amer. Water Works Assn., 70, 698.

Cadman, T. W., and Dellinger, R. W. 1974. "Techniques for Removing Metals from Process Wastewater," Chem. Eng., 81, 8, 79.

Calmon, C., and Gold, H. 1976. "New Directions in Ion Exchange," Environ. Sci. and Technol., 10, 980.

Centec Corp. 1980. "The Application of Ion Exchange to the Purification of Metal Finishing Wastewater for Recycle," U.S. EPA (IERL), Cincinnati, OH.

Clifford, D., et al. 1978. "Activated Alumina: Rediscovered 'Adsorbent' for Fluoride, Humic Acid and Silica," Ind. Water Eng., 15, 7, 6.

Eisenmann, J. L., and Smith, J. D. 1973, 1974. "Selective Nutrient Removal from Secondary Effluent," PB Rept. 228108, U. S. Natl. Tech. Info. Service, Springfield, Va. (1973); Chem. Abs., 81, 411103 (1974).

Gold, H., and Todisco, A. 1973. "Wastewater Reuse by Continuous Ion Exchange." In: Complete WateReuse-Industry's Opportunity, American Institute of Chemical Engineers, New York. p. 96.

Himsley, A., and McArvey, F. X. 1973, 1974. "Role of Ion Exchange Processes in Pollution Control," Ion Exch. Membranes, 1, 3, 148 (1973); Chem. Abs., 80, 124293u (1974).

Hinrichs, R. L., and Snoeyink, V. L. 1976. "Sorption of Benzenesulfonates by Weak Base Anion Exchange Resins," Water Res. (G. B.), 10, 79.

Kaup, E. G. 1974. "Reclamation of Acidic Mine Drainage Waters by Ion Exchange and Reverse Osmosis," American Institute of Chemical Engineer Symposium Series, Vol. 70 (136). p. 557.

Kammel, R., and Lieber, J. W. 1977. "Possibilities of Treating Electroplating Effluents Without the Formation of Residues. Metal Recovery in Place of Sludge Disposal, Part III." Galvanotechnik 68, 5, 413 (Ger.) (1977); Chem. Abs., 87, 90113n (1977).

Kim, B. R., et al. 1976. "Adsorption of Organic Compounds by Synthetic Resins," Jour. Water Poll. Control Fed., 48, 120.

Newman, J. 1974. "Moving Bed Ion-Exchange as a Re-Use Tool," American Institute of Chemical Engineers Symposium Series, Vol. 70 (136). p. 472.

Raman, R., and Karlson, E. L. 1977. "Reclamation of Chromic Acid Using Continuous Ion Exchange," Plat. Sur. Finish., 64, 8, 40, 42 (1977); Chem. Abs., 87, 143257w (1977).

Sato, E. 1976. "Treatment of Waste Water with Zeolite," Sen'i Kako (Jap.), 27, 12, 714 (1975); Chem. Abs., 85, 36823q (1976).

Scokart, P. O., et al. 1979. "The Chemistry and Surface Chemistry of Fluorinated Alumina," Jour. Colloid and Interface Sci., 70, 209.

Wu, Y. C., and Itemakin, I. C. 1979. "Removing Fluoride Ions with Continuously Fed Activated Alumina," Water and Sew. Works, 126, 2, 61.

Yabe, E. 1979. "Treatment of Plating Waste Solutions," Jap. Patent 79 75,159 (June 15, 1979); Chem. Abs., 91, 112096w (1979).

Stripping

McCance, K. E., and Burke, H. G. 1980. "Contaminated Condensate Stripping—an Industry Survey," Pulp Paper Mag. Can., 81, 11, 78.

Nathan, M. F. 1978. "Choosing a Process for Chloride Removal," Chem. Eng., 85, 3, 93.

Okamoto, Y., et al. 1978. "Application of Foam Separation to Aqueous Solutions of Trinitrotoluene (TNT). II, Removal of Organic Explosives with Surfactants," U. S. NTIS AD-A066 118/1WP.

Smit, A. C. M., and Kaasenbrood, P. J. C. 1976. "Treatment of Urea-Plant Effluents." Ind. Wastes, 22, 5 44.

Zajic, J. E., et al. 1979. "Foam Fractionation of Spent Sulfite Liquor. (1) Separation of Surfactants. (2) Separation of Toxic Components," Can. Jour. Chem. Eng., 58, 321 (1979); Abs. Bull. Inst. Pap. Chem., 50, 5772 (1979).

Chemical oxidation

Anon. 1975. "Phenols in Refinery Waste Water Can Be Oxidized with Hydrogen Peroxide," Oil and Gas J., Jan 20, 75, V73, N3, P84.

Anderson, G. L. 1977. "Ozonation of High Levels of Phenol in Water," Water--1976: I. Physical, Chemical Wastewater Treatment, Amer. Inst. Chem. Engr. Symp. Ser., 73, 166, 265.

Burbank, N. C., Jr., et al. 1977. "A Comparison of Ozone and Hydrogen Peroxide in the Emergency Oxidation of a Refinery Wastewater," Presented at Purdue University 32nd Industrial Waste Conf., Lafayette, Indiana.

Chen, K. Y., and Okey, R. W. 1977. "Univ of Southern California, Ozone Effect on Synthetic Rubber Waste Treatment," Industrial Wastes, Mar-Apr 77, V23, N2, P46.

Cunningham, N. J. 1978. "Unit Operations for Treatment of Hazardous Industrial Wastes-Chemical Oxidation," Noyes Data Corp Pollution Technology Review 47, P740.

El-Dib, Mohamed A., and Aly, Osama A. 1977. "Removal of Phenylamide Pesticides from Drinking Waters-I. Effect of Chemical Coagulation and Oxidants," Water Research, V11, N8, P611.

Garrison, R. L., Prengle, H. W., Jr., and Mauk, C. E. 1975. "Ozone-Based System Treats Plating Effluents," Metal Progress, Vol. 108 (6). p. 61.

Leduc, P. 1978. "Ozone Improves Taste, Odor and Color of Water," Waste and Sew. Works, 125, 12, 49.

Melnyk, P. B., Judkins, D., and Netzer, A. 1976. "An Ozone Reactor for Color Removal from Pulp Bleachery Wastes," Presented at Purdue Univ. Industrial Waste 31st Conf., Lafayette, IN, May 4-6. P434.

O'Neill, E. T., et al. 1979. "Tannery Waste Streams Meet Effluent Regulations Using Hydrogen Peroxide," Proc. 33rd Ind. Waste Conf., Purdue Univ. (Ann Arbor Science, Ann Arbor, Mich.), 1978, 471.

Snider, E. H., and Porter, J. J. 1974. "Ozone Treatment of Dye Waste," Jour. Water Poll. Control Fed., 46, 886.

Activated sludge

Carpenter, D. F., et al. 1978. "Microbial Transformation of (14) C-Labelled 2,4,6-Trinitrotoluene in an Activated Sludge System," Appl. Environ. Microbiol., 35, 949.

Foess, G. W., and Ericson, W. A. 1980. "Toxic Control--The Trend of the Future." Water and Wastes Eng., 17, 2, 21.

Holladay, D. W., et al. 1976. "Biodegradation of Phenolic Waste Liquors in Stirred-Tank, Columnar, and Fluidized Bed Bioreactors." U. S. Nat. Tech. Inf. Ser. CONF-761109-4.

Monning, E., Murphy, M., Zweidinger, R., and Little, L. 1980. "Treatability of Pesticide Manufacturing Wastewaters: Carbaryl," NTIS Report PB80-224306, Apr.

Nayar, S. C., and Sylvester, N. D. 1979. "Control of Phenol in Biological Reactors by Addition of Powdered Activated Carbon," Water Res. (G. B.), 13, 201.

Throop, W. M., and Mazewski, G. E. 1980. "Refinery Aerator Selection for Optimizing Effluent Results," Proc. 8th Annual WWEMA Ind. Poll. Conf., Houston, Tex., 329.

Wendt, T. M., and Kaplan, A. M. 1976. "A Chemical-Biological Treatment Process for Cellulose Nitrate Disposal," Jour. Water Poll. Control Fed., 48, 660.

Pyrolysis

Galandak, J., et al. 1979. "Design Considerations for Pyrolysis of Municipal Sludge," Journal Water Pollution Control Federation, Vol. 51, No. 2, February, pp. 370-377, 2626 Pennsylvania Ave., N.W., Washington, DC.

Feber, R. C., et al. 1977. "Synthetic Fuel Production from Solid Wastes." EPA, Municipal Environmental Research Laboratory, Office of Research and Development, Cincinnati, OH, NTIS PB-272 423.

Davidson, P. E., and Lucas, T. W. 1978. "The Andco-Torrax High Temperature Slagging Pyrolysis System," American Chemical Society - Division of Environmental Chemistry; Vol. 18, No. 1; 175th National Meeting; March 12-17. pp. 265-268.

Cone, E. T., and Preston, G. T. 1978. "Disposal of Sewage Sludge and Municipal Refuse by the Occidental Flash Pyrolysis Process,"

American Chemical Society - Division of Environmental Chemistry; Vol. 18, No. 1; 175th National Meeting, March 12-17. pp. 273-275.

Duvall, D. S., and Rubey, W. A. 1977. "Laboratory Evaluation of High-Temperature Destruction of Polychlorinated Biphenyls and Related Compounds," EPA-600/2-97-228, MERL, Cincinnati, OH, Dec.

Duvall, D. S., Rubey, W. A., and Mescher, J. A. 1980. "High Temperature Decomposition of Organic Hazardous Wastes." In Shultz, D., and Black, D. Treatment of Hazardous Waste: Proceedings of the Sixth Annual Research Symposium, EPA-600/9-80-011, U. S. Environmental Protection Agency, Washington, DC. p. 121.

Houston, K. C. 1980. "Incineration of Hazardous Waste at Sea," Presented at the EPA National Conference on Management of Uncontrolled Hazardous Waste Sites, Washington, D. C., October 15-17. Hazardous Materials Control Research Institute, 9300 Columbia Blvd., 'lver Spring, MD.

Photolysis

Archer, A. J., and Rosenthal, I. 1977. "Dye-Sensitized-Photo-Oxidation--A New Approach to the Treatment of Organic Matter in Sewage Effluents," Water Res. (G. B.), 11, 557.

Arisman, R. K., et al. 1980. "Destruction of PCB's in Industrial and Sanitary Waste Effluents by the ULTROX* (UV-Ozone) Process," Water--1979, AIChE Symp. Ser., 76, 197, 169.

Christensen, D. C., and Weimer, W. C. 1980. "Enhanced Photodegradation of Persistent Halogenated Organic Materials," Proc. 34th Ind. Waste Conf., Purdue Univ., 1979, Ann Arbor Science Publishers, Inc., Ann Arbor, MI, 160.

Oliver, B. G., and Carey, J. H. 1977. "Photochemical Production of Chlorinated Organics in Aqueous Solutions Containing Chlorine," Environ. Sci. and Technol., 11, 893.

Roth, M., and Murphy, J. M., Jr. 1978. "Ultraviolet-Ozone and Ultraviolet-Oxidant Treatment of Pink Water." U. S. NTIS AD-A064 106/8WP.

Sargent, J. W., and Sanks, R. L. 1974. "Light-Energized Oxidation of Organic Wastes," Jour. Water Poll. Control Fed., 46, 2547.

Chemical coagulation/flocculation plating

Ashton, A. 1980. "Primary Flocculation of Cadmium Plating Plant Effluent: Improved Occupational Hygiene as Effluent Quality," Water Poll. Control (G. B.), 79, 421.

Gebbie, P., and Sorensen, E. P. 1977. "Heavy Metal Removal from Electroplating Effluents," Met. Aust., 8, 11, 267-71 (1977); Chem. Abs., 87, 11043p (1977).

Hannah, S. A., et al. 1977. "Removal of Uncommon Trace Metals by Physical and Chemical Treatment Processes," Jour. Water Poll. Control Fed., 49, 2297.

Lanouette, K. H. 1977. "Heavy Metals Removal," Chem. Eng., 84, 22, 73.

Textiles

Eaddy, J. M., and Vann, J. W. 1978. "Physical/Chemical Treatment of Textile Finishing Wastewater for Process Reuse," EPA 600/2-79/079, U. S. Environmental Protection Agency. 141 pp.

Feigenbaum, H. N. 1978. "Process for Removal of Heavy Metals from Textile Waste Streams," Amer. Dyestuff Reptr., 67, 3, 43.

Kerwin, W. E., et al. 1977. "An Inorganic Pigments Manufacturer Cleans Up Its Wastewater," Proc. 31st Ind. Waste Conf., Purdue Univ., 1976, Ann Arbor Science Publishers, Inc., Ann Arbor, MI, 994.

Shelley, M. L., et al. 1976. "Evaluation of Chemical-Biological and Chemical-Physical Treatment for Textile Dyeing and Finishing Waste," Jour. Water Poll. Control Fed., 48, 753.

PART VII: DISPOSAL SYSTEMS

Introduction

A disposal system is a formulated or planned method or facility used to discharge, deposit, inject, dump, or place solid waste or hazardous waste into or on any land or water. The general categories used in this bibliography are landfills, subsurface injection, and ocean disposal. The different techniques grouped under disposal are collectively capable of handling wastes in solid, semi-solid, and liquid forms. Obviously, some techniques are better suited for certain waste forms than are others.

It should be remembered that radioactive waste disposal is regulated separately from those associated with RCRA and Superfund.

Landfilling

Landfilling involves the engineered burial of wastes. In general, a landfill consists of a large constructed pit or trench (lined or unlined) in which waste is placed over a period of time and later covered with soil. Landfills must be carefully designed and operated to provide long-term protection of groundwater, surface water, air, and human health from contaminant migration. Groundwater and surface water protection are generally achieved through use of low permeability, natural or synthetic liners, proper physical siting, appropriate design and operation of covering activities, use of leachate management systems, and provisions for long-term management through proper closure, postclosure, and monitoring activities. Air and human health protection are generally achieved by proper management of the landfilling operation: to prevent mixing of incompatible materials which could produce fires, explosions, or toxic fumes; to provide for segregation of materials in separate landfill cells; to provide for pretreatment of wastes; and to provide for proper cover on a daily or periodic basis.

After completion of the landfilling operation, the landfill must be properly closed using some kind of cover. The cover is required to prevent wind dispersal of the solids, avoid public contact with the waste, and act as a barrier to infiltrating liquid thus minimizing the production of leachate. Reviews of a book, a report, a manual, and an article are included.

Book: Cheremisinoff, N. P. 1979. Industrial and Hazardous Wastes Impoundments, Ann Arbor Science, Woburn, Mass. 488 pp.

Subject: Landfilling.

Description: This text is a complete overview of industrial and hazardous wastes impoundments. It presents effective procedures for the management, classification, treatment, and disposal of hazardous and toxic wastes, as well as the environmental impact of impoundment operations, with an emphasis on state and federal regulatory roles. Also discussed are ways of reducing the toxicity of some chemicals before disposal, and methods of pretreating sludge to make it acceptable for landfill use. A listing of materials suitable as liners for waste disposal facilities is included and the advantages and disadvantages of each are discussed. Disposal site selection, effects of surface runoff, landfill design considerations, and problems involved in establishing and enforcing state and federal regulations are also examined.

Report: Farb, D. G., 1978. "Upgrading Hazardous Waste Disposal Sites," EPA-500/SW-677, U. S. EPA, Washington, D. C. 41 pp.

Subject: Landfilling.

Description: Groundwater contamination problems, resulting from the indiscriminate disposal of potentially hazardous wastes, are complicated and usually more than one remedial procedure will be required to correct a groundwater contamination problem. Such contamination is typically the result of waste disposal practices which have led to an accumulation of solids, liquids, sludges, discarded containers, and miscellaneous debris. Remedial procedures may include:

(1) Infiltration controls.

(2) Waste excavation and burial at a new site.

(3) Leachate plume management by groundwater pumping.

(4) Leachate and groundwater treatment.

(5) Soil manipulation.

The final decision on which restoration approach(es) should be used should be based on an analysis on the following:

(1) Type of contaminant and its characteristics.

(2) Levels of contamination.

(3) Areal extent of contamination.

(4) Quantity of contaminant at the source.

(5) Technical feasibility of potential restoration methods.

(6) Economic feasibility of potential restoration methods.

(7) Institutional and political constraints, such as public opposition.

(8) Tangible and intangible costs of taking no action and thus abandoning the resource.

Manual: Moore, C. A. 1980. "Landfill and Surface Impoundment Performance Evaluation," U. S. EPA SW-869, 63 pp.

Subject: Landfilling.

Description: This Evaluation Procedures Manual has been developed to describe the technical approach and to present equations for determining how the design of hazardous waste surface impoundments and landfills will function in controlling the quantity of liquids released to the environment.

The procedures described herein should allow an evaluator to determine the adequacy of designs for:

(1) Compacted clay liners, or synthetic liners intended to impede the vertical flow of liquids.

(2) Sand or gravel drainage layers intended to convey liquids laterally into collection systems.

(3) Slopes on such liner systems.

(4) Spacings of collector drains.

Article: Sanning, D. E. 1981. "Surface Sealing to Minimize Leachate Generation at Uncontrolled Hazardous Waste Sites, Management of Uncontrolled Hazardous Waste Sites," U. S. Environmental Protection Agency and American Society of Civil Engineers, pp. 201-205.

Subject: Landfilling.

Description: Many existing technologies, such as those currently being used for construction, hydrologic investigation, wastewater treatment, spill cleanup, and chemical sampling and analysis, can be applied to uncontrolled hazardous waste sites. The minimization of surface infiltration will, in almost all cases, be an

integral part of the remedial steps at those sites where the waste has been buried and the cost of removal is prohibitive.

Minimizing surface infiltration typically consists of regrading, diverting surface water runoff, and preventing or eliminating infiltration. The effectiveness of surface sealing depends upon the contribution of surface infiltration to the total problem at the site. From the standpoint of cost-effectiveness and ease of applicability, minimizing surface infiltration poses marked advantages over other types of remedial action unit operations.

There has been a lot of local public resistance to siting of landfills around high population areas and even in some rural areas, and this trend will probably continue. Nevertheless, landfilling in a site that meets RCRA and state requirements will continue to be a viable and cost-effective disposal method for both sanitary and hazardous wastes.

Deep Well Injection

In general, a well injection is simply the subsurface emplacement of fluids through a bored, drilled, or driven well, or through a dug well, where the depth of a dug well is greater than the largest surface dimension. Injection wells must be designed to prevent fluid movement into underground sources of drinking water. The general requirements for underground injection wells are that they shall be located, designed, constructed, operated, maintained, and closed in a manner that will ensure protection of human health and the environment. Deep well injection should be considered only after all alternate methods have been reviewed and it has been concluded that hazardous liquid wastes cannot be treated or disposed of in other economical ways. The Bureau of Mines is active in enhancing the utility and continued feasibility of deep well injection. In some cases pretreatment is required to make the process a viable one and in some areas it was found that deep well injection could contribute to earth tremors and thus earthquake potentials. Of the documents reviewed, descriptions of three articles covering design, operations, and pretreatment requirements are included.

Article: Barlow, A. C. 1972. "Basic Disposal-Well Design," in Cook, T. D. (ed.) Underground Waste Management and Environmental Implications. Am. Ass. of Pet. Geo. Tulsa, OK. p. 72.

Subject: Deep Well Injection.

Description: Two factors, safety and utility, are basic in the design of disposal wells. Every means must be taken to ensure the safety of the installation so that the environment is protected against inadvertent pollution. Also, the well must be designed for maximum utility so that continued disposal of the waste is assured.

Disposal wells are of two general types - those which are considered open-hole completions and those which are "normal" completions (casing is run to total depth). Open-hole completions are common in those areas, such as along the Gulf Coast, where the disposal zones are in slightly consolidated or unconsolidated sands.

Article: Donaldson, E. C. 1972. "Injection Wells and Operations Today," in Cook, T. D. (ed.) Underground Waste Management and Environmental Implications. Am. Ass. of Pet. Geo., Tulsa, OK. p. 24.

Subject: Deep Well Injection.

Description: Bureau of Mines engineers have investigated the feasibility and limitations of the underground injection of industrial wastes by observing installations at industrial plants, cities, and oil fields. The chemical industry is using about 175 deep wells to inject approximately 30 million gal per day of waste solutions. The wastes are (1) inorganic salts, (2) mineral and organic acids, (3) basic solutions, (4) chlorinated and oxygenated hydrocarbons, and (5) municipal sewage.

The wells, ranging from 1,000 to 8,000 ft (300–2,440 m) deep, are completed in three general types of formations: (1) unconsolidated sand, (2) consolidated sandstone, and (3) vugular carbonate rock. The chemical and physical characteristics of the formation and waste dictate the design of the injection system and govern its operation.

Article: Sadow, R. D. 1972. "Pretreatment of Industrial Wastewaters for Subsurface Injection," in Cook, T. D. (ed.) Underground Waste Management and Environmental Implications. Am. Ass. of Pet. Geo., Tulsa, OK. pp. 93.

Subject: Deep Well Injection.

Description: To ensure success of a subsurface waste-disposal operation, surface pretreatment of the wastewater is generally required. Pretreatment can be quite expensive, but it can make the difference between a successful operation and one subject to repeated difficulties and even failure.

Reduction of formation permeabilities and porosity, face plugging, and precipitation and polymerization reactions will all lead to diminished acceptance rates and excessive backpressure levels. Injection compatibility is directly influenced by formation structure, interstitial water properties, and waste characteristics, including particle size of solids, pH, corrosiveness, viscosity, bacterial content, dissolved gases, temperature, and specific gravity.

Ocean Disposal

The term "disposal site" means an interim or finally approved and precise geographical area within which ocean dumping of wastes is permitted under conditions specified in sections 102 and 103 of the Marine Protection, Research, and Sanctuaries Act (PL 92-532). Such sites are identified by boundaries established by coordinates of latitude and longitude for each corner or by coordinates of latitude and longitude for the center point and a radius in nautical miles from that point.

An evaluation of all other alternatives must be made. This will include the relative environmental risks, impact, and cost for ocean dumping as opposed to other feasible alternatives such as:

a. Landfilling.

b. Well injection.

c. Incineration.

d. Spread of material over open ground.

e. Recycling of material for reuse.

f. Additional biological, chemical, or physical treatment of intermediate or final waste streams.

g. Storage.

No wastes will be deemed acceptable for ocean dumping unless such wastes can be dumped so as not to exceed the limiting permissible concentration (LPC) as defined in Subpart G of Part 227 of PL 92-532, provided that 227.8 does not apply to those containerized (227.11) and insoluble wastes (227.12). The total quantities of wastes dumped at a site may be limited as described in Part 228.8.

Ocean disposal sites must be managed as follows:

a. Times, rates, methods of disposal, quantities, and types of materials disposed of must be regulated.

b. Effective ambient monitoring programs for the site must be developed and maintained.

c. Disposal site evaluation and designation studies must be conducted.

d. Modifications for onsite use and/or designation must be recommended when needed.

The practice of ocean disposal of hazardous waste is nearing an end as international treaties are negotiated that impact on this practice. Conway and Ross (1980) addressed the subject briefly in their handbook on Industrial Waste Disposal. A review follows.

Book: Conway, R. A., and Ross, R. D. 1980. Handbook of Industrial Waste Disposal, Van Nostrand Reinhold Company, Atlanta.

Subject: Ocean Disposal.

Description: This handbook covers all facets of wastewater treatment and disposal of hazardous materials. Ocean disposed industrial wastes include caustic, chlorinated hydrocarbons, black liquor, ammonium sulfate, titanium pigment wastes, phenol, cyanides, and sodium metal. Barge transport and discharge procedures are reviewed. Ocean dumping is closely regulated in the United States by the Environmental Protection Agency.

The Marine Protection Research and Sanctuaries Act (Public Law 92-532) suggests all dumping be done beyond the continental shelf, but monitoring of these areas is difficult. The permits available for dumping are:

(1) Research Permit - impact of particular waste on environment.

(2) General Permit - small amounts of nontoxic waste.

(3) Special Permit - for wastes not included under the general permit, but do meet other ocean dumping criteria.

(4) Interim Permit - this permit is issued where material which exceeds established criteria must be dumped.

(5) Emergency Permits - may be issued for dumping after consultation with the Department of State and other appropriate persons or agencies.

Materials prohibited in other than trace quantities usually are heavy metals such as mercury and cadmium, organohalogens, and such materials as oil and grease.

Ocean disposal of wastes via incineration is discussed for Gulf of Mexico locations.

Other References

Henry, H. R., and Kohout, F. A. 1972. "Circulation Patterns of Saline Groundwater Affected by Geothermal Heating - as Related to Waste Disposal," in Cook, T. D. (ed.) Underground Waste Management and Environmental Implications. Am. Ass. of Pet. Geo. Tulsa, OK. pp. 202.

Swolfs, H. S. 1972. "Chemical Effects of Pore Fluids on Rock Properties," in Cook, T. D. (ed.) Underground Waste Management and Environmental Implications. Am. Ass. Pet. Geo. Tulsa, OK. pp. 224.

Witherspoon, P. A., and Neuman, S. P. 1972. "Hydrodynamics of Fluid Injection," in Cook, T. D. (ed.) Underground Waste Management and Environmental Implications. Am. Ass. of Pet. Geo. Tulsa, OK. pp. 258.

PART VIII: TEMPORARY STORAGE

Various methods of storage of hazardous wastes at disposal sites are described in the literature, including synthetic, collapsible tanks; earth embankments; encapsulation in pits and other structures such as concrete rings; and steel drums. Most of the technical literature is in the form of papers presented at professional meetings and commercial brochures.

Under the RCRA regulations, storage is identified as the containment of waste in such a manner as not to constitute disposal. Therefore, storage, particularly in the case of hazardous waste, should be considered viable only in cases where the accumulation of waste prior to treatment or disposal results in a cost reduction or makes some treatment process or disposal method more feasible. Examples include accumulation of waste until a sufficient volume is obtained for bulk shipment or bulk treatment thus greatly decreasing costs. Under the RCRA regulations, a hazardous waste generator may accumulate materials onsite without a permit for a period of 90 days as long as certain conditions are met as specified in CFR Title 40, Part 262, Subpart C, Section 262.34.

Another problem area involves the storage of wastes that emit or produce toxic fumes in receptacles that are open or vented to the atmosphere and thereby allow emission of such fumes. EPA has not finalized the regulations concerning air emissions from such storage facilities but probably will do so in the near future. Until such time as these regulations are finalized, the owner/operator of a storage facility must use his own judgment with respect to the open storage of volatile waste. In general, such wastes should not be stored in a manner which allows for the emission of fumes except possibly in emergency situations.

The terminology used in discussing the storage of hazardous materials is somewhat unique. Therefore, a few terms are repeated here for the convenience of the reader.

a. Container - Any portable device in which material is stored, transported, treated, disposed of, or otherwise handled including barrels, drums, bottles, cylinders, boxes, etc.

b. Tank - A stationary device designed to contain an accumulation of hazardous waste, constructed primarily of nonearthen materials (e.g., wood, concrete, steel, plastic) that provide structural support.

c. Surface Impoundments - A facility or part of a facility which is a natural topographic depression, man-made excavation, or diked area formed primarily of earthen materials (although it may be lined with man-made materials). Impoundments are designed to hold an accumulation of liquid wastes or wastes containing free liquids and are not injection wells. Examples of surface impoundments are holding, storage, settl'ng, and aeration pits, ponds, and lagoons.

d. Waste Pile - A noncontainerized accumulation of solid nonflowing waste. Waste piles are generally small, are maintained in buildings or outside on concrete or other pads, and are typically composed of a single dry material.

The articles and reviews included relate primarily to the design of storage containers that may ultimately be used for burial. An EPA technical monograph, an article on burial container/design, several commercial brochures on containers, a report on steel container strength test, and a report on encapsulation procedures are included.

Technical Monograph: USEPA. 1981. "Technical Methods for Investigating Sites Containing Hazardous Substances - Sample Handling, Packaging, and Shipping Procedures," Technical Monograph No. 22, 11 pp.

Subject: Waste Packaging and Shipping.

Description: After a sample is taken, it must be dealt with in a manner which will ensure accurate analytical results and safety during shipping and analysis. The precautions, techniques, and legal requirements used to ensure the integrity of the sample and the safety of those handling the sample are addressed in this monograph.

If the samples have been taken in support of a legal case, it is necessary to maintain proper custody of the samples and to carefully document any changes of sample custody. To simplify this, it is recommended that as few people as possible handle the samples. A sample is under one's custody if:

(1) It is in one's actual possession or

(2) It is in one's view, after being in his physical possession, or

(3) It was in one's physical possession and then locked up to prevent tampering, or

(4) It is in a designated and identified secure area.

Article: Mahalingam, R., et al. 1981. "Simulation of Solidification Temperature Profiles in the Polyester Process for Immobilization of Hazardous Wastes," Ind. Eng. Chem. Process Des. Dev., Vol. 20, No. 1, pp. 85-90.

Subject: Design of a Burial Container.

Description: As part of the development of a process for immobilizing hazardous wastes in a polyester matrix, an analysis is provided here for the prediction of temperature profiles during curing of the emulsion, by consideration of reaction exotherms and polymerization kinetics. Such analyses should be helpful in the optimal design of burial containers. 29 refs.

Commercial Brochure: Uniroyal, Inc. Undated. "Collapsible Containers for Shipping and Storage," promotional brochures, Uniroyal, Inc., Mishawaka, IN.

Subject: Flexible Storage Tanks for Liquids.

Description: Brochure describes and gives specs for flexible storage tanks and drains for storage of liquids. Product line includes:

(1) Sealdrums.

A 500-gallon (1,890-liter) Sealdrum holds the same volume of liquids as ten 55-gallon (208.1-liter) rigid drums. They can be flown, rolled, or towed over virtually any terrain. Emptied, they collapse to 15% of full size.

(2) Static storage tanks.

Tough nylon fabric, both sides coated with polyurethane, enables these 250- to 100,000-gallon (945- to 378,500-liter) tanks to withstand searing desert heat or arctic temperatures to -52°C (-61°F). They provide optimum resistance to fuel wicking, diffusion, and evaporation loss. Hold virtually any fluid, especially water or fuel, and collapse to a fraction of size when empty for easy transport. A 10,000-gallon (37,800-liter) size weighs only 296 lb (135 kg).

(3) Sealed tanks.

Sealed tanks come in 1,500- to 4,570-gallons (5,670- to 17,290-liter) capacities. Vans or flatbed trucks can be converted to tankers in minutes. Sealed tanks are unrolled like a carpet, filled, and strapped down. They haul liquids one way, dry cargo on return, and collapse to less than 10% of their full size.

Commercial Brochure: Firestone Coated Fabrics Company. 1978. "Presenting the Embankment-Supported FABRITANK®," Magnolia, AR.

Subject: Waste Containers.

Description: This promotional brochure for Fabritank® collapsible containers describes development, tank, embankment, handling and installation, material, etc.

Fabritank® collapsible containers are light-weight but durable rubber-coated fabric tanks supported and protected by simple earthen dikes. They are the most practical and economical means ever devised for storing large volumes of liquid.

The embankment Fabritank® is being used today to store water for fire protection, drinking, and process water for domestic and commercial uses. Standard sizes are listed in this brochure. Other sizes, including capacities over one million gallons, can be supplied to suit requirements for both temporary and permanent storage.

Report: Balmert, M. C. 1979. "Seale Model Impact Tests of Hazardous Material Container Designed to Section VII, Division 1, of the ASME Code," American Society of Mechanical Engineers Paper No. 79-PVP-42, 9 p.

Subject: Strength Tests of Steel Containers.

Description: Drop tests were performed on two scale models of a hazardous material stainless steel pressure vessel, designed to the ASME Code, Section VIII, Division 1. This vessel was surrounded by an energy absorber (low density balsa wood) and a thin steel jacket. Each model (1/4 and 1/3 scale) was subjected to four impacts: three 9-m (30-ft) drops (each end and side) onto concrete reinforced steel pads and 1.0-m (40-in.) drop onto a mild steel bar. Since hazardous material regulations do not specify accident conditions, these tests were selected from 10 CFR 71 criteria for nuclear material packaging. All tests were instrumented with strain gages and photographed on high speed film. Although occasionally some test fittings failed, results indicated that the pressure vessels themselves remained intact after the complete test sequence. 3 refs.

Report: Lubowitz, H. R., and Wiles, C. C. 1978. "Encapsulation Technique for Control of Hazardous Materials," in Land Disposal of Hazardous Wastes, Proc, 4th Ann. Research Symposium, San Antonio, Texas, U. S. EPA, Cincinnati, Ohio, pp. 342-356.

Subject: Encapsulation of Hazardous Wastes.

Description: A process using polyolefins and fiberglass to encapsulate containers holding hazardous wastes was researched, developed, and evaluated on a laboratory scale. The process is geared to reinforce deteriorating containers in order to secure their hazardous consignments in subsequent handling operations and under environmental conditions existing in a direct disposal site such as a landfill. Polyolefins were employed because they provide a unique combination of low cost, abundance, chemical stability, mechanical toughness, and flexibility. Fiberglass is low cost, prevalent, chemically stable, stiff, and load bearing. Encapsulate test specimens (right cylinders, 3-inch dia. x 4-inch ht.) were fabricated by fashioning cylindrically shaped fiberglass casings, having walls about 1/50 inch thick, and then forming 1/4-inch-thick jackets by fusion of powdered high density polyethylene (HDPE) upon the surfaces of the casings. The test specimens were thus rendered seamless. Mainly, two types of specimens were produced, some filled with sand and some hollow. A set of sandfilled ones were charged with aqueous solutions of heavy metals (simulating loss of container contents within an encapsulate) and then examined with respect to their ability to secure metal contaminants under aqueous leaching conditions. They were found to hold their contents secure in leaching by water and by a strong solvent for metals such as dilute hydrochloric acid. Hollow and filler containing specimens were employed to evaluate mechanical performance of encapsulates. These, under appreciable mechanical pressure, were found to maintain their dimensional integrity. Under extreme pressures, they underwent distortion, yet their jackets did not fail even though their casings were flawed by the mechanical stresses. The above results indicate the processes' ability to prevent, or limit to acceptable levels, the release or delocalization of hazardous waste from deteriorating containers in manipulation and in final disposition.

PART IX: CONSTRUCTION PROCEDURES

Introduction

Few guidelines exist for the construction of hazardous waste disposal facilities specifically. General construction methods, principles, and equipment are discussed at length in two voluminous books by Nichols (1962) and by Peurifoy (1956). Two CE manuals pertaining to the design and construction of levees in general and of retaining dikes for containment of dredged material have application to construction as a remedial technique at uncontrolled disposal sites. Reviews of these two books and the two manuals are included. Most other literature consists of articles that report on operations, with some construction detail, at existing waste disposal facilities worldwide. These are shown as "Other References."

Book: Nichols, H. L., Jr. 1962. Moving the Earth: The Workbook of Excavation, North Castle Books, Greenwich, Connecticut.

Subject: Techniques and Equipment.

Description: This book might be considered a "bible" for the construction industry. Its 1300-plus pages are divided into two major parts: The Work, and The Machines. "The Work" covers principles and techniques in land clearing, surveys and measurements, excavation and construction in soil and mud, cellar construction, ditching and dewatering, ponds (including earth dam construction, materials, cutoff trench, settling and cracking, seepage, etc.), landscaping and grading, road construction, and costs (bookkeeping). "The Machines" seems a complete guide to selection, maintenance, and operation of the gamut of excavation equipment (up to 20 years ago). The book should be considered a general reference for construction.

Book: Peurifoy, R. L. 1956. Construction Planning, Equipment and Methods, McGraw-Hill Book Co. Inc., New York.

Subject: Construction Procedures.

Description: The book is a general reference on all types of construction activities in soil and rock. Although dated, it presents engineering and construction fundamentals applicable today. It considers excavating equipment and describes techniques, planning, and equipment for tunneling, foundation grouting, pile

driving, pumping (incl. dewatering), cofferdams, aggregate concrete works, and safety engineering.

Manual: Office, Chief of Engineers, Department of the Army. 1980 (Oct). "Design and Construction of Retaining Dikes for Containment of Dredged Material," Engineer Manual EM 1110-2-5008, Washington, D. C., 177 pp. and Appendices.

Subject: Construction Procedures.

Description: The manual develops guidelines for design and construction of containment area retaining structures. It recommends field and laboratory investigation programs, investigation procedures for borrow areas, dike design parameters, and construction methods. It describes causes of dike instability and recommends methods and procedures for analyzing dike stability with respect to foundation/embankment shear strength, seepage, settlement, and external erosion. The manual discusses dike construction techniques and considerations for three methods: hauled dikes, cast dikes, and hydraulic fill dikes. Appendix A presents examples of slope stability analyses by the circular arc, wedge, planes, infinite slope, and bearing capacity methods.

Manual: Office, Chief of Engineers, Department of the Army. 1977 (Nov). "Design and Construction of Levees," Engineer Manual EM 1110-2-1913, Washington, D.C.

Subject: Construction Procedures.

Description: This Engineer Manual serves as a guide to the design and construction of earth levees. The distinction is made between levees, which are not subjected to long periods of saturation, and earth embankments, which are subjected to constant saturation. Waste disposal sites fall into the latter category, but the levee manual presents design, investigation, and construction principles and techniques pertinent to many earthworks. The first six chapters suggest and describe field investigations; laboratory testing of borrow areas and levee foundation soils; treatment and consideration of borrow areas; seepage control by drains, wells, berms, filters, etc.; and embankment slope design. A chapter is devoted to levee construction, and construction methods are classified as compacted, semicompacted, and uncompacted. Foundation preparation, improvement of foundation stability, and embankment construction are described in the chapter on construction. Appendices are devoted to mathematical analysis of underseepage and subsurface pressure, design of seepage berms, relief well installation, and filter design. The manual is pertinent to operations in poorly drained areas on weak foundations, as found in many waste disposal areas.

Selected Specific Safety and Health Issues

This is covered in Parts II and III of this bibliography but because some of the problems encountered that relate to the safety and health of the workers are unique or require extreme caution, they are repeated here, in brief, for emphasis. Some of the key problems are listed below.

Combustible gases. There are a variety of toxic solvents which could collect in surface depressions during remedial actions and thereby pose fire or explosion hazards.

Trench ventilation. Some remedial actions involve the construction of trenches with layered fill material for the purpose of collecting toxic gases and/or leachate. Construction operations may require workers to perform various activities in the bottom of these trenches where toxic gases may escape from the trench walls and collect in the trench.

Unearthing of wastes. During the excavation and other earthwork required for certain remedial action operations, it is possible that drums containing wastes are encountered or other direct contact with waste materials is made.

Other situations. There will undoubtedly be other site-specific situations that will require additional planning and development efforts by safety and health personnel so that remedial actions do not result in endangerment of the worker or the surrounding community.

Health and safety support contract. General considerations for a construction support contract are:

a. Site-specific safety plan including protective clothing.

b. Ambient monitoring program (including analysis).

c. Personnel training.

d. Medical monitoring.

e. Oversee onsite operations and provide first aid.

f. Design and oversee decontamination process.

Other References

The references shown below relate to site-specific construction and operational procedures on a worldwide variety of problems.

Edwards, W. J., and Ward, N. C. 1969 (Aug). "Oil Waste Disposal Facility Study, Seattle Area," Municipality, Metro, Seattle, Engineering Report, 51 pp.

North Atlantic Treaty Organization. 1977 (May). "Disposal of Hazardous Wastes: Landfill," 90 pp.

NATO Committee on Challenges to Modern Society. 1976. "Pilot Study, Disposal of Hazardous Wastes; the Gallenbach Special Refuse Deposit," International Experts Conference, Bonn.

Reindl, J. 1977 (Nov). "Operational Efficiencies Must Be Built Into Site at Design Stage," Solid Waste Management, Vol. 20, No. 11.

Sittig, M. 1979. "Landfill Disposal of Hazardous Wastes and Sludges," Noyes Data Corporation, Park Ridge, NJ.

Snyder, H. J., Jr., Rice, G. B., and Skujins, J. J. 1976 (Jul). "Disposal of Waste Oil Re-refining Residues by Land Farming," in Residual Management by Land Disposal, Proceedings of the Hazardous Waste Research Symposium, U. S. EPA, Cincinnati, Ohio, pp. 195-205.

PART X: MONITORING PROCEDURES

Introduction

The preceding chapters reviewed the techniques of identifying, treating, storing, and disposing of hazardous materials, and the outlined procedures have implied monitoring scenarios. The monitoring is primarily for safety and determination of effectiveness of treatment and disposal systems. Monitoring of environmental parameters will usually be required before, during, and after completion of a remedial action. The basic objectives of a monitoring system are to:

a. Measure effectiveness of the remedial action taken.

b. Detect possible breakdown or system failure.

c. Detect groundwater, air, and surface water contamination.

Groundwater Monitoring

The requirements for groundwater monitoring associated with facilities permitted under Interim Status are given in 40 CFR Part 265 and those for New Facilities are given in 40 CFR Part 267, respectively. In general, the major steps in establishing a groundwater monitoring system include:

a. Establishment of a data base of background values of water quality.

b. Determination of groundwater gradient.

c. Placement of adequately designed wells.

d. Sampling of groundwater.

e. Chemical analysis of samples.

f. Interpretation of data.

g. Evaluation of monitoring system.

Reviews of three articles dealing with the priorities and methodologies for groundwater monitoring at hazardous waste disposal sites are included.

Article: Unterberg, W., Stone, W. L., and Tafuri, A. N. 1981. "Rationale for Determining Priorities and Extent of Cleanup of Uncontrolled Hazardous Waste Sites, Management of Uncontrolled Hazardous Waste Sites," U. S. Environmental Protection Agency and American Society of Civil Engineers, pp. 188-197.

Subject: Objectives of Operating and Monitoring Procedures.

Description: The Comprehensive Environmental Response, Compensation and Liability Act of 1980, PL 96-510, requires revision of the National Contingency Plan with a section known as the National Hazardous Substance Response-Plan and requires that the plan establish procedures and standards for responding to releases of hazardous substances, pollutants, and contaminants. One aspect of this new plan is defined as:

"105 methods and criteria for determining the appropriate extent of removal, remedy, and other measures as required by this Act."

In this paper the authors attempt to develop a rationale for determining "appropriate extent of removal" for uncontrolled hazardous waste sites. This involves three types of decisions:

(1) Determination of Cleanup Priorities

(2) Evaluation of Alternative Cleanup Methods and Selection of Optimum Methods

(3) Determination of Extent of Cleanup (How Clean Is Clean) or How Dirty is Dirty

Article: Morrisson, R., and Ross, D. 1978 (Apr). "Monitoring for Groundwater Contamination at Hazardous Waste Disposal Sites," Proceedings, Control of Hazardous Material Spills, pp. 281-286.

Subject: Groundwater Monitoring.

Description: Increased awareness of the potential for water contamination from hazardous waste disposal sites has resulted in a need for reliable methods to identify and quantify disposal site emissions. Development of a disposal site monitoring program is based on an understanding of 3 factors—the physical and chemical characteristics of wastes received or formerly received at the site, the hydrogeological conditions at the site and in the region's drainage basin, and sampling methodologies adaptable to the specific conditions present at the site. Hazardous wastes fall into 1 of 5 categories—toxic, radioactive, flammable, explosive, and biologically hazardous. The most probable disposal method available for each of these 5 wastes is tabulated; only lagooning, sanitary landfill, and chemical landfill disposal provide an environment conducive to monitoring of groundwater degradation. The most frequent cause of failure in a well-operated program stems

from a lack of understanding of the site's hydrogeologic characteristics, climatological setting, and surface drainage patterns. A site-specific monitoring plan can be developed from data derived from hazardous waste assessment and disposal site characteristics. A simplified model which can be used in most situations is described. Sampling of interstitial waters below a hazardous disposal site can supplement a groundwater monitoring program through the use of a vacuum-pressure lysimeter and moisture cells. Devices developed for monitoring oily waste lagoons, radioactive wastes, pesticides, sludges, and various others are divided into 2 categories--conventional wells and pneumatic ejection systems.

Article: Huggins, A., and Roffman, H. K. 1980. "Methodologies for Assessing Groundwater Contamination by Hazardous Wastes," Proceedings Annual Tech. Meeting Institute Environmental Sciences, 26th, Philadelphia, pp. 328-332.

Subject: Groundwater Monitoring.

Description: Groundwater contamination principally from hazardous waste has only recently gained federal recognition with the passage of the Resource Conservation and Recovery Act (RCRA) in 1976. Methodologies for assessment of the leaching potential of hazardous wastes as well as groundwater transport of leached materials have been presented in RCRA regulations. This paper describes the special nature of groundwater contamination problems, reviews relevant portions of RCRA, and provides a critique of the more commonly used methods to assess groundwater contamination. It suggests that both leaching tests and groundwater monitoring systems be designed in relation to waste-specific and site-specific characteristics.

Air Quality and Gas Monitoring

Air quality and gas monitoring particularly before and during the remedial action is essential at almost all sites and some sites will require the installation of systems for monitoring after the action is completed.

Article: Sullivan, D. A., and Strauss, J. B. 1981. "Air Monitoring of a Hazardous Waste Site," Management of Uncontrolled Hazardous Waste Sites, Hazardous Materials Control Research Institute, Silver Spring, Md., pp. 136-142.

Subject: Air Quality Sampling.

Description: Versar, Inc., performed ambient air sampling at Rollins Environmental Services' waste treatment and disposal facility near Baton Rouge, La. Solid adsorption columns containing Tenax or activated charcoal were used for sampling a gas chromatograph (GC) and a gas chromatography/mass spectrometer (GC/MS) were used for sample analysis.

Report: USEPA. 1982. "Handbook for Remedial Action at Waste Disposal Sites," EPA 625/6-82-006, Washington, D.C.

Subject: Remedial Actions - Construction Operations and Monitoring.

Description: A technical handbook for developing remedial action plans for the cleanup of polluting waste disposal sites is provided. The manual is divided into 3 parts. First is a summary of the flow of contaminants from a land disposal site, the remedial actions available for site cleanup and a metholology for plan development. The second section provides the reader with detailed information on remedial action options with respect to general description; applications; design, construction, and operating considerations; advantages and disadvantages; and installation and annual operating costs. The appendix presents a discussion of various treatment modules of wastewater treatment unit operations and costs in terms of applicability to various waste types. Major design and construction parameters, as well as advantages and disadvantages and costs, are discussed for the following treatment modules: flow equilization; precipitation, flocculation, and sedimentation; biological treatment (air-activated sludge, pure oxygen-activated sludge, trickling filters, rotating biological discs, biological seeding, stabilization ponds/aerated lagoons); carbon adsorption; ion exchange; liquid ion exchange; ammonia stripping; wet air oxidation; and chlorination.

The appendix also includes surface controls, groundwater controls, leachate controls, gas migration controls, and direct waste treatment methods such as excavation, hydraulic dredging, land disposal, incineration, wet air oxidation, solidification, encapsulation, in situ treatment, etc.

Surface Water Control

Control of runoff during construction and after the remedial action is completed must be addressed. The USEPA Handbook (see review in preceding paragraph) is an excellent reference document as is the "Annotated Bibliography for Diffuse Source Pollutant Control." A review of this document follows.

Report: Cullinane, M. J., et al. 1982. "An Annotated Bibliography for Diffuse Source Pollutant Control," U. S. Army Engineer Waterways Experiment Station, Vicksburg, Miss., MP-EL-82-

Subject: Runoff Control.

Description: The national concern for the preservation and protection of the environment has resulted in legislation and regulation that makes mandatory the consideration of environmental quality, both short and long term, in any development activity undertaken by the CE, including both military and civil works construction activity. In addition, the impacts of non-CE development activities such as uncontrolled disposal sites on or near CE projects are of major concern.

Contaminants may result from the construction and operation of the CE activity itself, emanate as a result of lessee or concessionaire activities on CE lands, or be generated by activities conducted adjacent to CE activities.

The ability to collect runoff and effectively treat it to reduce the pollutant load on a receiving body of water has been demonstrated as has the ability to reduce or contain runoff through structural or nonstructural alternatives. The evaluation and control of nonpoint sources of pollutants through engineering solutions is the topic of this annotated bibliography and its purpose is to present CE personnel with an overview of currently available information concerning diffuse source pollutant evaluation and control technologies.

Other References

Disposal

Braids, O. C., et al. 1977. "Effects of Industrial Hazardous Waste Disposal on the Ground Water Resource," Drinking Water Quality Enhancement Through Source Protection, R. B. Pojasek (ed.), pp. 179-207.

Fields, T., Jr., and Lindsey, A. W. 1975. "Landfill Disposal of Hazardous Waste: A Review of Literature and Known Approaches," EPA-530/SW-165, U. S. Environmental Protection Agency, Washington, DC 36 pp.

Gibb, J. P. 1976 (Sep). "Field Verification of Hazardous Waste Migration from Land Disposal Sites," Proceedings, Disposal of Residues on Land, St. Louis, MO.

Lawless, E. W., Ferguson, T. L., and Meiners, A. F. 1975. "Guidelines for the Disposal of Small Quantities of Unused Pesticides," EPA 670/2-75-057, U. S. EPA, Washington, D. C., p. 331 (also distributed by National Technical Information Service, Springfield, VA, as PB-244-557).

Mercer, R. B., Malone, P. G., and Broughton, J. D. 1978. "Field Evaluation of Chemically Stabilized Sludges," Land Disposal of Hazardous Wastes, Proc. 4th Ann. Research Symposium, San Antonio, Texas, U. S. EPA, Cincinnati, OH, pp. 357-365.

Walker, W. H. 1974. "Monitoring Toxic Chemical Pollution from Land Disposal Sites in Humid Regions," Ground Water, Vol. 12 No. 4, p. 213.

Air Sampling

Kolnsberg, H. J. 1976. "Technical Manual for Measurement of Fugitive Emissions: Upwind/Downwind Sampling Method for Industrial Emissions," U. S. EPA, Industrial Environmental Research Laboratory, EPA-600/2-76-089a, 75 pp., Cincinnati, OH.

McCord, A. T. 1981. "A Study of the Emission Rate of Volatile Compounds from Lagoons," Management of Uncontrolled Hazardous Waste Sites, Hazardous Materials Control Research Institute, Silver Spring, MD, pp. 129-135.

Spittler, T. M., and Oi, A. W. 1981. "Ambient Monitoring for Specific Volatile Organics Using a Sensitive Portable PID GC," Management of Uncontrolled Hazardous Waste Sites, Hazardous Materials Control Research Institute, Silver Spring, MD, p. 122.

Surface Runoff Control

Lederman, P. B., et al. 1981. "Design of a Treatment System for Hazardous Run-Off," Management of Uncontrolled Hazardous Waste Sites, Hazardous Materials Control Research Institute, Silver Spring, MD, pp. 194-300.

In accordance with letter from DAEN-RDC, DAEN-ASI dated 22 July 1977, Subject: Facsimile Catalog Cards for Laboratory Technical Publications, a facsimile catalog card in Library of Congress MARC format is reproduced below.

Green, Andrew J.
An annotated bibliography for cleanup of hazardous waste disposal sites / by Andrew J. Green (Environmental Laboratory, U.S. Army Engineer Waterways Experiment Station). -- Vicksburg, Miss. : The Station ; Springfield, Va. ; available from NTIS, 1982.
155 p. in various pagings : ill. ; 27 cm -- (Miscellaneous paper ; EL-82-7)
Cover title.
"October 1982."
Final report.
"Prepared for Office, Chief of Engineers, U.S. Army."
Includes bibliographies.

1. Hazardous substances--Bibliography. 2. Pollution--Bibliography. I. United States. Army. Corps of Engineers. Office of the Chief of Engineers. II. U.S. Army Engineer

Green, Andrew J.
An annotated bibliography for cleanup of hazardous : ... 1982.
(Card 2)

Waterways Experiment Station. Environmental Laboratory. III. Title IV. Series: Miscellaneous paper (U.S. Army Engineer Waterways Experiment Station) ; EL-82-7.
TA7.W34m no.EL-82-7